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THE

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BOSTON, MASS.

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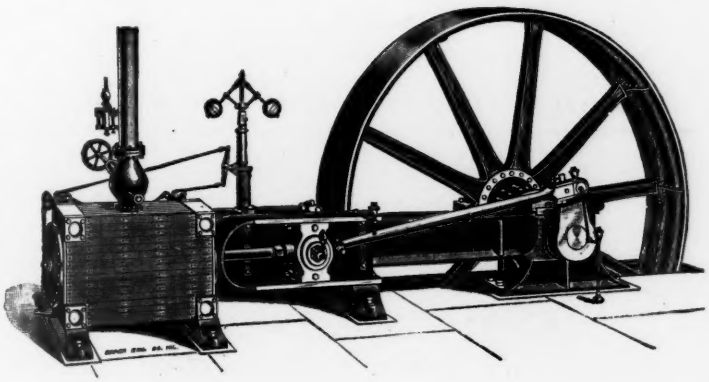

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THE TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

THE TECHNOLOGY QUARTERLY is a scientific journal, published by the Society of Arts, Massachusetts Institute of Technology. It is intended that each volume shall contain articles of permanent value in the various departments of scientific investigation carried on at the Institute or by its graduates, including Mathematics, Engineering, Metallurgy, Chemistry, Physics, Biology, History, Economics, Geology, etc. It will contain, also, the Proceedings of the Society of Arts and the principal papers read before the Society.

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BOSTON, MASS.

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AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. VII. APRIL, 1894. NO. 1.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-SECOND YEAR, 1893-94.

THURSDAY, January 11, 1894.

THE 453d meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Professor Lanza in the chair.

A paper on the "Australian Wool Exhibit at the World's Columbian Exposition" was presented by Mr. Henry G. Kittredge, of Boston. The paper is printed in full in the present number of the *Quarterly*. The Chairman extended the thanks of the Society to Mr. Kittredge, and declared the meeting adjourned.

THURSDAY, February 8, 1894.

The 454th meeting of the SOCIETY OF ARTS was held in the Engineering Laboratories of the Institute this day at 8 P.M., Mr. Henry M. Howe in the chair.

The records of the previous meeting were read and approved.

Mr. William Tracy Eustis, of Brookline, was duly elected an Associate Member of the Society.

The following papers were read by title:

"Some Experiments for Determining the Refractoriness of Fire-Clays," by H. O. Hofman and C. D. Demond.

"On an Apparatus for the Measurement of Coefficients of Self-Induction and the Investigation of the Phenomena of Alternating Currents," by Frank A. Laws.

"Matrices which Represent Vectors," by W. H. Metzler, Ph.D.

The Chairman then introduced Professor Gaetano Lanza, of the Institute, who spoke briefly of the principles governing the construction of testing machines and then described in detail the 300,000-pound Emery testing machine and the 100,000-pound beam testing machine. He was followed by Professor E. F. Miller, of the Institute, who described the new torsion testing machine. Tests were then made on these machines. A spruce column, $8'' \times 8''.1 \times 16'$, was broken by compression in the Emery machine under a maximum load of 156,800 pounds; a yellow pine beam was broken in the beam machine under a maximum load of 13,500 pounds; and a Norway iron bar, $2''$ in diameter and $6'$ long, was twisted off after seventeen revolutions in the torsion machine under a maximum load of 75,000 inch-pounds twisting moment.

At the close of the tests the meeting adjourned.

FRIDAY, March 9, 1894.

The 455th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Prof. Dwight Porter in the chair.

The records of the previous meeting were read and approved.

Mr. Charles B. Appleton, of Brookline, Mr. J. Holly Craig, Mr. J. E. Moultrop, and Dr. H. F. Libby, of Boston, were duly elected Associate Members of the Society.

The following papers were read by title:

"Tests on the Efficiency of Jack-Screws," by E. F. Miller and W. A. Johnston.

"Classification of Economic Geological Deposits Based on Origin and Original Structure," by W. O. Crosby.

The Chairman then introduced Mr. Charles H. Dalton, of the Subway Commission, who addressed the Society on the subject of the difficulties of transportation of passengers and merchandise in Boston and the relief offered by the proposed Tremont Street Subway. He was followed by Professor George F. Swain, of the Commission, who described and explained, with the aid of plans and a model, the pro-

posed route and construction of the subway. Mr. E. T. Wheelwright, City Architect of Boston, gave a brief description of the arrangement of the stations

The meeting then adjourned.

THURSDAY, March 22, 1894.

The 456th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Mr. C. J. H. Woodbury in the chair.

The records of the previous meeting were read and approved.

Mr. Edgar H. Mumford, of Netherwood, New Jersey, was duly elected an Associate Member of the Society.

The Chairman then introduced Mr. William Danmar, of Brooklyn, who read a paper on "The Wood Architecture of Switzerland." The paper was very fully illustrated, and is printed in the present number of the *Quarterly*. A short discussion on the adaptation of Swiss architectural principles to American conditions, in which the Chairman and others took part, followed.

The thanks of the Society were voted to Mr. Danmar for his very interesting and instructive paper, and the meeting adjourned.

CLEMENT W. ANDREWS, *Secretary.*

NEW SOUTH WALES WOOL EXHIBIT AT THE WORLD'S COLUMBIAN EXPOSITION.

By HENRY G. KITTREDGE.

Read January 11, 1894.

The foreign-wool exhibit at the World's Columbian Exposition had a twofold interest to Americans, because of its great intrinsic merit and of the part it is likely to play in the near future in the manufacturing industry of the country as representative of the wools that will enter our ports in large quantities free of duty. No finer exhibit of foreign wools was ever before seen in the United States. The Argentina wool exhibit was a revelation to our manufacturers for its great excellence, more because of their unfamiliarity with the wools which the exhibit represented than for any particular points of superiority which it possessed over that from Australia. In case of the importation of wool free of duty, the Argentina wools, both the Merino and the cross breds, will be more seriously considered for our manufactures than would have been the case had no exhibit of this kind been made.

It is my purpose, however, to confine my remarks to the wool exhibit of New South Wales, with an occasional allusion to that of Victoria, Australia. The colony of New South Wales is the mother colony of the Australian group. Her wool exhibit was under the immediate charge of Alexander Bruce, chief government inspector of stock in the colony, and for the past forty years identified with the pastoral industry of Australia. To him is due the credit of eradicating the scab disease from among the sheep flocks of New South Wales by strictly enforcing the law requiring thorough dipping of sheep at shearing time in prophylactic decoctions.

The New South Wales exhibit contained representative wools from all the sheep districts of the colony except those of Cobar, Ivanhoe, and eleven small districts, whose flocks numbered, in 1891, 2,400,000 sheep. Thus less than 4 per cent. of the number of sheep in the

colony were unrepresented at the Fair, and this small proportion was confined chiefly to the uninviting region between the Lachlan and Darling Rivers. There are 63 sheep districts in New South Wales, and 20 wool districts, containing altogether, according to the 1891 stock returns, about 62,000,000 sheep. By reference to the map, the various wool districts, or nineteen of them, will be seen indicated upon it. It will be observed that the railway intersects most of them. The wool districts, according to their importance in the number of sheep, are as follows:

	Sheep.
Lachlan	5,452,571
Riverina	5,231,146
Upper Murrumbidgee	5,099,381
Upper Darling	4,808,672
Western Darling	4,745,382
Southern Riverina	4,101,115
Castlereagh	4,076,196
Liverpool Plains	4,055,365
Namoi	3,909,830
Western Riverina	3,267,946
Bathurst	2,979,550
Gwydir	2,856,598
New England	2,581,642
Bogan	1,709,055
Monaro	1,439,841
Mudgee	1,181,644
Hunter River	695,152
Goulburn	641,428
Lower Darling	631,176
Total	59,463,990

Over 37 per cent. of this number of sheep are in the districts between the Lachlan and Murray Rivers; over 24 per cent. in the northern districts, from Castlereagh River to the upper tributaries of the Darling River; and nearly 14 per cent. in the upper and western Darling districts.

There are about 13,200 sheep owners in New South Wales; 750 of these own over 62 per cent. of the whole number of sheep. The flocks owned by these large proprietors range in size from 20,000 to 500,000 and 600,000 sheep. Seventy-three of these own nearly one sixth of all the sheep in the colony, distributed among the different wool districts as follows:

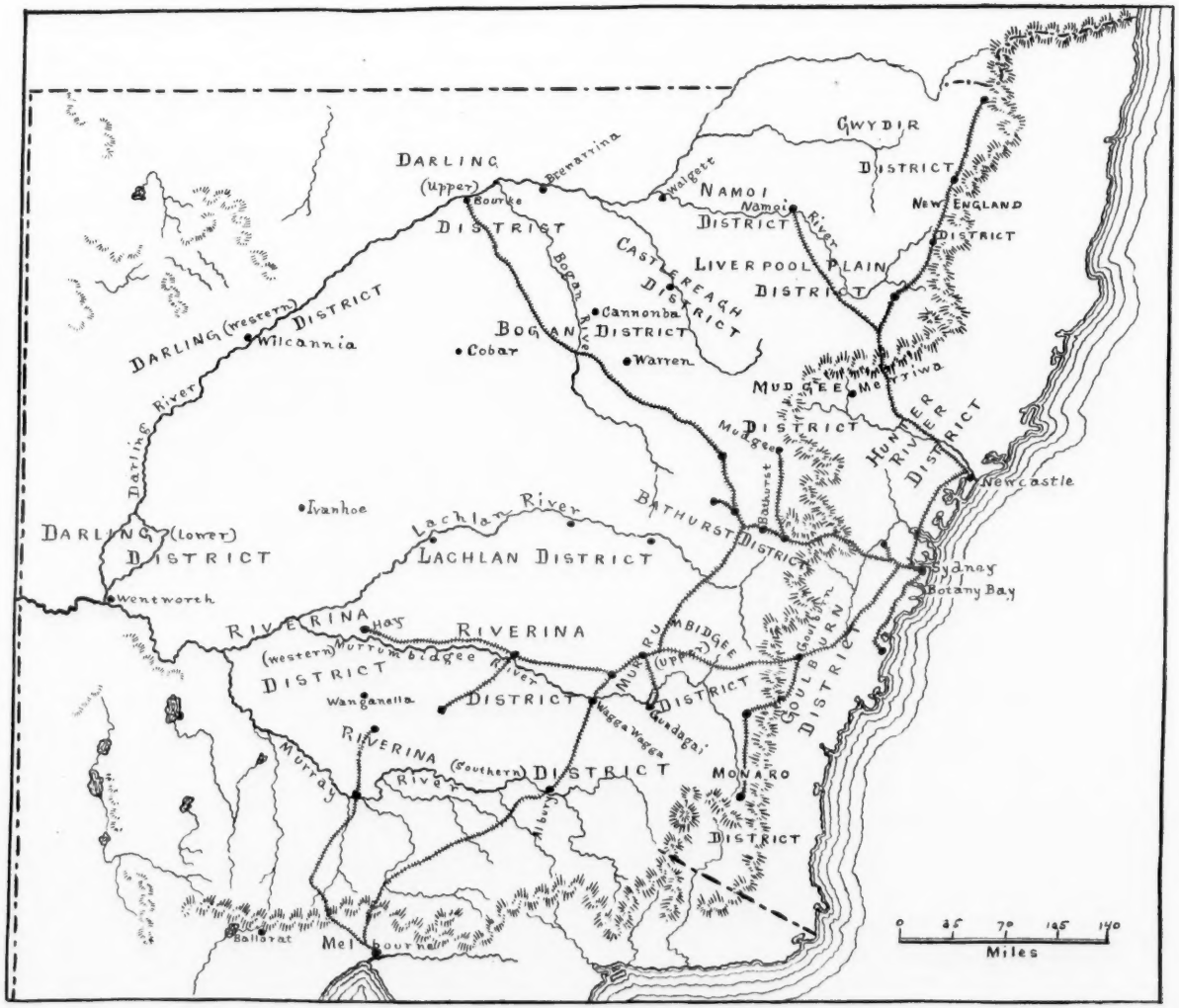
Seventeen in the Riverina and Lachlan districts, owning 2,528,704 sheep; 15 in the Upper Darling, Bogan, and Castlereagh districts,

owning 2,548,384 sheep; 19 in the Gwydir, Liverpool Plain, and Namoi districts, owning 2,440,785 sheep; 18 in the Western and Lower Darling districts, owning 2,420,398 sheep; and 4 in the district about Cobar and Ivanhoe, owning 454,503 sheep. The great flocks are west of the western slope of the mountain range.

The various breeds of sheep in the colony are the Merino long-wooled sheep, as the Lincoln, Leicester, Downs, and Romney Marsh, and the cross breds, principally the long-wooled breeds with the Merino. Over 97 per cent. of the sheep are Merinos. Over 70 per cent. of the Merino sheep yield combing wool, the remainder yielding clothing wool. Over 17 per cent. of the combing-wool sheep produce a superfine grade of wool, and about 46 per cent. a medium grade. Of the long-wooled sheep the Lincoln is in the greatest favor, though the Leicester is in no mean repute. It is generally thought among the flock masters of Australia that there is no room for improvement in the quality of the Merino fleece by any further admixture of European or American blood. Some efforts have been made in the direction of building up the avoirdupois of the animal, but they have not proved generally successful, as deterioration in the quality of the wool has followed. Large carcasses for mutton, as experience has demonstrated the world over, are inconsistent with superiority in the fineness of wool.

The geographical position of Australia is a grand one, an ideal one for sheep husbandry, where the climate is neither too hot nor too cold, tempered by the breezes that come over the surrounding sea, and where the air is clear and dry. On the east coast there is a chain of mountains generally known as the Great Dividing Range, extending north and south some 1,500 miles, in many places coming within 30 miles of the ocean, and touching it at Point Danger, between Queensland and New South Wales. Its highest elevation is in the southern part of New South Wales, where Mount Kosciusko rises 7,120 feet above the sea level, and where snow may be found at all times of the year. The colonies of New South Wales and Victoria occupy the choicest parts of the continent, where the climate is congenial, and where the best lands are to be found for pastoral and agricultural pursuits.

New South Wales is divided into three physical divisions, designated as the coast district, the mountain district, and the western district. The latter two we shall have most to do with in connection


DARLING (upper) DISTRICT
Bourke
Bererrina
Walgett
NAMOI DISTRICT
Namoi River
GWYDIR DISTRICT
NEW ENGLAND DISTRICT
LIVERPOOL PLAIN DISTRICT
CASTLEREAGH DISTRICT
Bogan River
BOGAN DISTRICT
Cannonba
Cobar
Warren
DARLING (western) DISTRICT
Wilcannia
Darling River
MUDGEE DISTRICT
Mudgee
HUNTER RIVER DISTRICT
Newcastle
Ivanhoe
Lachlan River
BATHURST DISTRICT
Bathurst
DARLING (lower) DISTRICT
LACHLAN DISTRICT
Sydney
Botany Bay
Wentworth
RIVERINA (western) DISTRICT
Hay
Murrumbidgee River
RIVERINA DISTRICT
MURRUMBIDGEE (upper) DISTRICT
GOULBURN DISTRICT
Wanganella
Wagga Wagga
Gundagai
RIVERINA (southern) DISTRICT
MONARO DISTRICT
Murray River
Murray
Ballarat
Melbourne
0 35 70 105 140
Miles

with my subject. The coast district is a narrow strip of land from 30 to 150 miles wide, watered by a number of small streams having their sources in the mountains. The home of the mutton breeds of sheep is distinctively to be found here. The mountain district embraces the high lands and elevated plains that extend the whole length of the colony and slope gradually toward the west. This district varies in width from 120 to 200 miles. With the extension of the railway system and the increase in population this district is becoming more agricultural and less pastoral. The soil is rich and highly productive; the herbage is excellent, and were it not for the higher wants of agriculture the land would be taken up from choice for the pasturage of sheep instead of that further to the west. The western district includes all the area from the elevated plains to the Darling River and beyond. All this region is now given over to grazing purposes, and with a general system of irrigation, as is now in contemplation, it will become equal if not superior to the most beautiful parts of the colony for husbandry of all kinds. As it is, sheep thrive there in a remarkable degree, very largely on account of the dry and healthy character of the climate. All the great rivers of the colony are found in this district. From Bathurst, northward to the 25th degree of latitude, all the western streams are tributary to the Darling River. This river is navigable from Walgett to its junction with the Murray River, 1,758 miles, thence to the sea. At some periods of the year its waters are very low; but four, and oftentimes twelve, months' navigation can be depended on as far as Bourke. This allows the transportation of wool and other things at certain seasons. The Murray River and its tributaries form the most important river system in the colony. The Murray has never been known to be dry, being fed by the heavy rains and snow on the mountains about Mount Kosciusko. This perennial flow in such steady volume cannot be said of any other stream in the colony west of the mountains. It is navigable from Albury to the sea, 1,703 miles. The Murrumbidgee River is navigable up to Gundagai, while the Lachlan is navigable for several hundred miles. The great triangular region in the western district, lying between the Lachlan, Bogan, and Darling Rivers, has no surface streams. It is a comparative desert, yet some of the flocks of sheep in Australia are pastured there, about Cobar and Ivanhoe. The wools of this section were the only ones of New South Wales not represented in the World's Fair exhibit. The country northwest of the Darling River, notwithstand-

ing its undulating formation, has, also, no surface streams of consequence, and the few streams there have their beginning and ending in the sands, excepting at occasional flood times, when one or two of the principal ones empty their waters into the Darling. Were it not for this lack of surface water the western plains of New South Wales would be the finest pastoral country in the world. This objection, however, bids fair to be overcome at no very distant time by the sinking of deep wells, by means of which the underground waters can be brought to the surface in abundance. Experiments have been made in this direction sufficient to establish a reasonable amount of certainty that it is possible to obtain an unfailing supply of water from below the surface.

The region west of the Lachlan and Bogan districts is the salt bush country of New South Wales. It is not regarded with particular favor for the raising of fine-wooled sheep, on account of the heat and the vegetation peculiar to a light, sandy soil of saline characteristics. But this region is improving, as the country east of it has improved and is improving, for both pastoral and agricultural purposes. All of this broad expanse of country is for the Merino, not the mutton, sheep. While the Merino sheep will not thrive in the coast region because of the climate being too moist, the mutton sheep will not thrive in the interior on account of the climate being too dry. But the mutton breeds are not good for a new country for reasons distinct from climate.

The climate of Australia has had a peculiar influence upon the fleece and fiber of Merino wool, improving it in most all particulars. The wool has been made softer and more elastic. If there has been any deterioration it is in the density of the fleece; but this has been made good in a large degree by increased length of staple, so that there has been little or no loss in the weight of the fleece. It is difficult to say in what locality climate has had the most beneficial effect upon the fleece of the Merino. Certain it is that no place has been found superior in this respect to the Mudgee district, where an experience of over sixty years has shown that no better wool has been grown than there. So far as experimental knowledge goes this district may be considered as possessing all the essential elements for the superior growth of Merino wool. The mean annual temperature of Mudgee is about the same as that about Nice in Southern France. It is very much like that of the great sheep walks of Spain. The mean

maximum temperature in the hottest months is about 86°, and the mean minimum temperature in the coldest months is about 38°, taking the records of 1891 as a standard.

The rainfall for that year was 34 inches, but this was 27 per cent. above the average, the mean annual rainfall being nearer 26 inches. The mean annual rainfall in the Bathurst (24), Upper Murrumbidgee (23), and Liverpool Plain (25) districts is about the same — a few inches less. The mean annual rainfall through the Darling River valley is 12 inches at Wentworth, 13 inches at Wilcannia, 16 inches at Bourke, and 19 inches at Walgett. In the Bogan district the mean annual rainfall is 17 inches, while about Cobar and Ivanhoe it is only 12 inches, but through the Riverina districts it is from 26 to 28 inches.

Ever since 1820 there has been a constant improvement in the breeding and preparation of wool for the market. It was about this time that sheep breeding was commenced in the Mudgee district. In 1860 special attention was directed toward improving the fineness of the wool, owing to the increased demand for it at relatively high prices. This led to the importation of French, German, and American blooded Merinos, of the Rambouillet, Negretti, and Vermont types, respectively. The German and American Merinos were in special favor, chiefly for the density of their fleece. Improvement in the length of staple soon followed, because of the increased demand for it for combing purposes. A change in the style of breeding resulted in more attention being given to purely Australian bred sheep, which were found to possess special qualifications for the growth of long-stapled wool, not observed in those imported from Europe or America.

The French, German, and American bloods, however, were conspicuous in the specimens of New South Wales wools at the World's Fair. The Vermont blood was found almost, if not wholly, pure in some of the specimens from the Gwydir, New England, and Riverina districts. It was prominent in crosses with Australian types of wool, known as the Wanganella, Collaroy, and Tasmanian. The German blood was found almost pure in specimens from the Hunter River and Mudgee districts. The Collaroy blood, being the name of a stud flock at Merriwa, is derived from a Rambouillet and Saxon cross, and appeared to be a favorite infusion in many of the specimens from the Upper Darling, Gwydir, Namoi, and Monaro districts, and pure in many of the specimens from the Bathurst, Bogan, Castlereagh, Gwy-

dir, Hunter River, Liverpool Plain, and Mudgee districts. Some of the Collaroy fleeces weighed 18 to 19 pounds. The Collaroy-blooded wool is characterized for luster, evenness, and length of staple. The Collaroy and Brinley Park estates at Merriwa are famous for the high character of their Merino blooded flocks. The Brinley Park wool was represented by two specimens at the World's Fair. The sheep from which this wool was taken are descendants of a few rams and ewes imported into Australia, in 1830, from Silesia. Subsequent importations were made, one being made in 1860 of several rams from the renowned flocks of Prince Lichnowski. Great care has always been practiced in culling and selecting. This blooded wool secured high honors at the Philadelphia Exposition of 1876. The Mudgee district type of wool is noted for the comparative density of its fleece. It possesses certain distinctive features that give it a classification of its own, and as such was better represented in the wool exhibits at the World's Fair than that of any other. It appeared pure in specimens from nearly all the districts, or crossed with the Tasmanian and other bloods. Another well-known blood in the Mudgee district, the Havilah, was represented in a single specimen — one bale — at the Fair, but it failed to attract particular notice. The sheep from which the wool was taken had been pastured on poor soil, badly infested with grass seed. The blood, however, is in good repute in Australia for producing wool that is lustrous and supple and suitable for worsted and hosiery yarns. The wools of Liverpool Plains are chiefly of the Tasmanian, Mudgee, and Collaroy types. In some of these there are traces of Saxon and French blood that was first imported in 1825, and afterwards renewed by some Negretti blooded sheep from Germany. These wools in time came to be regarded as pure Australian Merino wools, being improved from time to time by infusions of blood from the Mudgee district, as the Collaroy, and from the famous stud flock of the Ercildoune estate, Burrumbeet, Victoria. In regard to the Ercildoune wool it may be well to state that the sheep can trace a pretty direct lineage from the first great importation of Spanish Merino sheep into Germany, in 1785, by the Elector of Saxony.

A portion of the electoral flock was afterwards purchased and taken to Tasmania, and from the Tasmanian flock thus established a few sheep were taken, in 1838, to start a flock upon Lake Burrumbeet, near Ballarat, that afterward came to be known as the Ercildoune. This latter flock has undergone much classing and selection, till its

wool has attained a standard of quality for fineness, elasticity, softness, and luster that has no superior. It is highly esteemed for mixing with silk. Some of this wool can be spun into worsted as fine as No. 140. In order to accomplish this the wool would have to be as fine as the finest Silesia and Saxony. This means that one pound of this yarn will extend over 44 miles in length. Victorian wools are in more or less favor with American manufacturers. Take the wool, for instance, grown in the neighborhood of Ballarat, as the Lismore wool, which is prized for its light condition and strength of staple. It commands a high price for worsted and hosiery purposes. This wool will spin into Nos. 60 and 70. Victorian wools are characterized by their bold and lustrous qualities, while the Riverina wools are esteemed for their soft and silky properties, and the South Australian for their length, strength, and metallic brightness, with a tendency toward coarseness.

The wools in the Namoi district, New South Wales, are very much of the Walgett type, as represented in some specimens seen at the World's Fair. These wools are raised with special reference to the country in which they are grown, the fleeces being dense and the tips inclined to fuzziness, preventing the heat and dust from penetrating into the fleeces and thus injuring the wool. These qualities are secured by certain crosses of Victorian, South Australian, and Riverina bloods. An objection has been raised concerning these wools on account of their hairy or fuzzy tips producing an excess of noils, yet they are capable of producing good worsted yarns of Nos. 60 to 70. The wools grown in the Upper Darling district, as about Brewarrina, are similar to those about Walgett; that is, the fleeces have more or less fuzzy tips. Yet this style of wool is looked upon as particularly useful, considering the circumstances under which it is grown. The heat and dust to which the sheep are exposed have a tendency to produce open, loose, hairy tips. Fineness of fiber is not arrived at, but a fiber of medium quality, of good length, that will spin down to about No. 60. Bogan district wool is not unlike that of the neighboring districts, being of medium grade, spinning into the 50's, and in some instances into the 60's. The fleeces are apt to be light on the tip, and, therefore, noil considerably. The wools of the Western Darling district show more or less poverty in the better characteristics of Australian wool. The summer heat is unpropitious for the growth of heavy fleeces. Every effort is being made to improve the wool by

the introduction of blood from the best stud flocks of Victoria and South Australia, particularly the latter. It is doubtful if wools of the first quality are ever raised in this section. A fuzzy tip characterizes the fleece. The Riverina districts produce a variety of grades of wool. Some of the best grown in Australia are produced there. Take, for instance, some of the wool exhibited at the Fair from Wagga Wagga, in which Vermont and Mudgee bloods were prominent. The specimens represented a superior type of combing wool. Some of the most perfect wools in the world are produced in this district, being bright, silky, fine, and lustrous. The wools of the Southern Riverina district at the Fair were of a high character. Those from Mulwala, west of Albury, were particularly noticeable. These came from a flock of sheep descended from Mudgee, Ercildoune, and Tasmanian blooded stock. Trade objections have been made to some of the wools from this section because of a wasty top, causing a large percentage of noils. Seasons, however, have much to do with these defects.

The heaviest fleeces of Australia come generally from Victoria. They become lighter as one goes toward Queensland. The fleeces are more open and freer from yolk. This applies more particularly to the wool grown in the western districts of New South Wales. The average weight of Australian fleeces from stock sheep may be put at six to seven pounds. A plain, not wrinkled sheep is preferred. The advantage of the infusion of American, or Vermont, blood is that it imparts a density to the fleece which it is difficult to get from the Tasmanian or Mudgee blood. The objection to it is that it gives to the wool a harsher feeling, and the staple is shorter than what is obtained from the stud flocks of purely Australian blood.

The great superiority of Australian wool is supposed to be due mainly to climatic conditions, but no little credit is also due to the grasses and herbage upon which the sheep feed. The native grasses of Australia are looked upon as superior for pasture to exotic grasses. Experience has inclined opinion that way. They possess greater reproductive powers, and there is very little necessity for reseeding. The most abundant variety of grass is that known as the Kangaroo, which not only supplies the sheep with nutritious food but is capable of resisting heat. It is found over all portions of New South Wales and Victoria, and is perennial. It is pronounced by all as being one of the finest and most useful of grasses for pasturage. It sometimes attains the height of three feet when on rich soil. In the autumn,

when its foliage turns brown, its nutritive qualities are said to be at the highest, and when cut as the flower stems appear it makes excellent hay. There are other native grasses of great value, among them the millet, which is found throughout New South Wales and is much liked by all stock, and the small burr grass and the variety known as the Wallaby, both of which are favorites with sheep. There are some troublesome weeds in Australia, as the Bathurst burr — known in the United States as the cockle burr — the trefoil burr, and certain thistles. These are exotic, having been introduced from abroad. In the western parts of New South Wales there are indigenous grasses that are perennial and possess fattening qualities even when dried up. The several varieties of the salt bush, a forage plant, grow there, thriving on the arid plains in most adverse seasons of heat and drought.

It is not to be presumed that the arid regions of Australia will always remain as they are now, of little value even for ordinary pastoral pursuits. The soil is undoubtedly naturally rich, requiring only a proper amount of moisture, properly distributed throughout the season, to become highly productive. To accomplish this most desired end a general system of irrigation is contemplated, especially in New South Wales, involving the sinking of artesian wells and the diversion of water courses. In Victoria no efforts of any moment have been made to obtain water by means of artesian wells, but ditching has been resorted to, and immense tanks constructed for the conservation of rainfall against times of drought. To allow any material increase in the number of sheep in the interior regions it will become necessary to resort to some expedient of this kind to supply surface water for the vegetation. The sinking of artesian wells in New South Wales first received government attention in 1879, and the first practical effort made in this direction was in 1884, near Bourke, where a flow was obtained of 24,000 gallons a day from a depth of 89 feet. Other wells have since been sunk in different localities, in most cases with satisfactory results, in one instance obtaining a flow of 2,000,000 gallons a day. The government is working upon a system of boring series of artesian wells in two lines — one extending from the mountain range to the western boundary, and the other from the Murray River to Queensland. The great river systems of the colony can, and unquestionably will, be utilized for irrigation purposes before many years pass by. It has been carefully estimated that the underground supply of water is all sufficient, and obtainable by means of sunken

wells, to convert the arid regions into highly productive ones. Take, for example, the 200,000 square miles area drained by the Darling River. The average rainfall over this is 20 inches per annum, and, even assuming that one tenth of this finds its way into the Darling and its tributaries, in order to carry off the water the river would have to be 200 feet wide and 100 feet deep all the year round, which was never known to be the case even in flood times. The water, therefore, must sink into the ground and flow at a lower level. If this lower level can be reached, and the water brought to the surface and distributed by economical means, the whole aspect of the interior districts of the colony will be changed and verdure prevail where aridity now exists.

Few sheep are now shepherded in Australia. The paddocking system is almost invariably in vogue. By this system the country is capable of carrying one third more sheep, the fleeces are better in condition and in all other respects, and the wool longer and stronger. The sheep themselves grow to larger size, live longer, and are freer from foot rot and disease. In addition to all this the expense of watching and caring for the sheep is less, and more time is at the command of the owner to devote to the improvement of his flock. In Victoria all the sheep stations are now inclosed by fences, and most of them are divided into paddocks. It has been found that more sheep can be kept and made to thrive on land under fence than when left open for general pasturage. Fencing has become a matter of preference as well as one of necessity. The question of cost is of secondary importance; in fact, it is fully offset by the improvement in the health and condition of the sheep and in the less expense and trouble attending their care. The cost of establishing a fenced run or paddock is covered in five years by the saving in the cost of labor alone. At first fences were made of logs and brush, where these were obtainable, but now nothing but wire is employed in their construction, at a cost of from $125 to $150 per mile. The usual height of a fence is three feet, with the wire strung at intervals of about six inches, on stout posts set 120 feet apart. Between these latter are placed smaller posts or stakes at distances sufficient to keep the wires in place. Some runs have several hundred miles of fences. These large runs are divided into many paddocks or inclosures. An average paddock is of about 800 acres in size. In New South Wales there are about 42,000 runs, of which over four fifths are inclosed, and seven

tenths of these are subdivided into paddocks. The area comprised in these holdings is not far from 190,000,000 acres. This would make the average run of about 4,500 acres. Over 80 per cent. of these holdings are leased from the colonial government. All, or nearly all, of the best sheep country in the Australian colonies is now occupied, and any additional increase in the number of sheep which the country can be made to carry must be effected by improvements in the way of irrigation and the character of the herbage. The management of a station consists usually of a manager, an overseer, a bookkeeper, and a certain number of boundary riders and common laborers, according to circumstances. The fencing in of sheep runs and their divisions into paddocks has had much to do toward the extermination of the scab disease among sheep. The last license for scabby sheep in Victoria was issued in October, 1874, and on June 6, 1876, the governor proclaimed the colony clean of the disease.

The extermination was accomplished through the rigid enforcement of the Scab Act of 1870, still in force, which requires certain medicaments to be used in the dipping of sheep, consisting of a mixture of tobacco and sulphur in water or of a mixture of lime and sulphur in water, the mixture in either case to be at a temperature of not less than 100° F. at the time of dipping. Two immersions are required at an interval of not less than seven nor more than fourteen days. The lime and sulphur dip is acknowledged to be effective, but it is regarded by sheep men as too severe, making the skin dry and the wool harsh. A preferable receipt, because of its milder action upon the skin and wool, yet equally efficacious for the eradication of the scab, is the tobacco and sulphur one at a temperature of about 104° F.

The loss of sheep on account of disease due to natural causes is almost as nothing compared with that caused by the multitude of rabbits that infest the land by eating up everything that is green and leaving nothing upon which the sheep can feed. With the exception of drought, there is no impediment to profitable sheep husbandry so damaging as the rabbit pest. Colonial laws have been directed toward its complete elimination at a great cost to those engaged in pastoral pursuit, with the great object of extermination still unaccomplished. The colony of New South Wales alone expended during the eight years ending with 1890 nearly $4,300,000 on account of rabbit destruction, and over 40 per cent. of this was derived from assess-

ments, the balance coming from the general revenue. There are various means resorted to for ridding the country of rabbits, such as trapping, poisoning the food and water, shooting, and hunting with packs of dogs. Some idea may be had of the destruction that has been going on among rabbits by the exports statistics of rabbit skins from Victoria. For the ten years ending with 1886 there were exported from that colony nearly 29,000,000 rabbit skins.

The shearing season in Australia depends on the location, beginning about the first of July in Queensland and ending about the first of March in Victoria. Thus there is given fully eight months for shearers to ply their vocation, commencing in the northern parts and completing their season's labor in the southern parts. Four months are allowed for rest and return to the north. Much skill is required in the shearing and handling of sheep, and the compensation is rated accordingly. There is a large class of men who do nothing else but follow this employment, which is now subject to rigid regulations in conformity with an agreement reached in 1891 between representatives of the Pastoralists' Federal Council of Australia and representatives of the Amalgamated Shearers' Union of Australia. Both of these associations are strong in number and in their organization, and the 1891 agreement was the result of a number of seasons' dissensions, but more particularly the result of a general strike on the part of the shearers the year before, when in many instances sheep remained unshorn till long after the usual time. The main cause of the strike was the employment of "non-union" shearers; but under the agreement employers are free to employ, and shearers are free to accept employment, whether belonging to shearers' or other unions, or not, without favor, molestation, or intimidation on either side. The meaning of all this is "freedom of contract." In New South Wales the agreement establishes the price of shearing at 20 shillings for every 100 sheep shorn, except rams, for which 40 shillings are paid for every 100 shorn. The employer is bound to keep the shearer fully supplied with sheep unless prevented by weather or by some unforeseen cause, and also to provide him with hut accommodations, cooking and table utensils, wood and water free of charge. Certain requirements are made in shearing. First, the sheep must be carefully taken from the pen to the shearing board and the belly wool removed first, where practicable, and laid aside. In opening the fleece at the neck and belly both blades of the shears of the machine must be kept

under the wool and close to the skin, so as to avoid twice cutting, and the shearer is not allowed to run the shears through the fleece so as to break it down the center or the back, or to stand on the fleece. The shearer is prohibited from kicking or ill-using any sheep. He is forbidden bringing intoxicating liquor into the station or using profane or obscene language in the shed. Shearers are obliged to provide their own cook, except where cooks work conjointly for shearers and employer, in which case the cook is engaged mutually by the employer and shearers. No shearer can be compelled to work more than forty-eight hours a week.

Shearing by machinery is something of very recent date, long desired by the wool growers of the colonies. Of the sixty-nine applications for patents on sheep-shearing machines only three or four have been received with favor, and at the Royal Agricultural Show, held at Melbourne in 1891, only three competed for the prize offered — the Wolseley, Burgon, and one other. The special merits of the Burgon machine are represented to be overhead safety driving motion, which is self-adjusting in its action, and can be operated separately from others on the same line of shafting, and a flexible steel driving shaft made of hardened steel with universal joints. It requires an engine of four-horse power to drive ten to fifteen of these machines. The best-known machine in the colonies is the Wolseley, not dissimilar in essential principles to the one just described, and first brought to public notice in 1887. Since then it is calculated that at least 60,000,000 sheep have been shorn by it. There is a variance in the opinion of sheep men as to the economy and general advantage of machine over hand shearing, though the testimony seems to be generally in favor of the machine. The chief complaint against it is its vibration and the extra strength required in holding the sheep to the shears. For a flock of 30,000 to 40,000 sheep there are required fourteen shearers, two packers, four sorters, one classer, two pickers-up, one sweeper, three or four general-utility men, two cooks, beside an engine driver, water hauler, and cutter grinder, in case the labor is done by machinery.

As required by the rules of shearing already referred to, the shearer is required to remove the belly wool, if practicable. This wool is carried by the pickers-up to the bins provided for such wool by the side of those for pieces, broken fleeces, etc. The fleeces go to the sorters, who place them upon tables with wire netting tops, the

meshes of which are about 1¼ inches in size. The sorter is an important person, oftentimes one who has had experience in the sorting room of an English factory, and therefore skilled in the art of quickly judging the different qualities of which the fleece is composed.

The fleece is sorted with the cut side down, the loose locks falling through the meshes of the netting onto the floor. The sorter is under the direction of the classer, who is the one chiefly responsible for the proper separation of the fleece into its several parts, an operation known among wool men as "skirting." After the skirting is all done the body of the fleece alone is left, and this is the only kind of wool that is sent to the American market. Technically, this is called the fleece, the rest being termed the first pieces, which are taken from the neck and from a portion of the skirts; the second pieces, taken from the upper part of the legs; the third pieces, taken from the cheeks, topknot, and lower part of the legs; the stained pieces, taken from the breach; the bellies, taken from the under parts, and the broken pieces, or trimmings, not included in the foregoing. After all these pieces, etc., are removed from the body of the fleece, the latter is folded lengthwise, rolled, and either tied with cotton twine or secured by twisting in an end of the fleece. The classer receives the wool in this condition and throws it into its proper bin, from which it is taken and pressed into bales of about 400 pounds in weight. Fleeces, whether Merino or crossbred, are classed as first, second, and third combing, or as first, second, and third clothing, as the case may be. Parts of fleeces have various designations, aside from first, second, third pieces, etc., as "dingy fleeces," "ram's fleeces," "tender fleeces," etc. This matter of sorting and classing wool is carried to an extreme, and, in the opinion of many, to an extent that is uncalled for. The stained bellies and locks from the fleece are generally scoured before being put upon the market. According to the record of one flock of sheep in the Riverina territory, the following proportion of classes and sorts was made: 47 per cent. first combing, 4 per cent. second combing, 2 per cent. clothing, ½ per cent. dingy and black, 19 per cent. broken fleece, 4 per cent. first pieces, 8 per cent. bellies, 8 per cent. stained, and 7½ per cent. locks. Twenty-four per cent., nearly, of this clip of wool was scoured, and only 53 per cent. was marketed in the form of fleeces.

The tendency is toward shearing in the grease, which is almost exclusively due to the price obtained for washed wool not being com-

mensurate with the cost of washing. Over 96 per cent. of the sheep shorn in New South Wales in 1891 were shorn in the grease; in 1880 the proportion did not exceed 70 per cent., 17 per cent. being creek washed. The average weight of fleeces shorn in the grease in 1891 was five pounds nine ounces, packed in bales measuring about five feet in length and two feet two inches in breadth and depth, and weighing about 450 pounds. The bales are afterward subjected to hydraulic pressure, and reduced in size about one half before exportation.

Wool is transported from the stations to the nearest railway by wagons, drawn either by horses or oxen, twenty of the latter often being yoked to one wagon, upon which is loaded as many as 25 bales of wool, and in exceptional cases as many as 50 bales. The cost of cartage overland is at the rate of $1.25 per 100 pounds per 100 miles. Should the distance exceed 100 miles, a discount of 20 per cent. from this rate is made for the additional number of miles. The railway freight from Hay, for instance, to Sydney, a distance of 454 miles, is about 70 cents a hundred pounds of greasy wool; from Bourke to Sydney, a distance of 503 miles, the freight is about 98 cents a hundred pounds; and from Mudgee to Sydney, a distance of 195 miles, the freight is about 66 cents a hundred pounds. It is a matter of report that "not so very many years have elapsed since the Queensland squatter, after seeing his last wagonload started from his station for the coast, would take a run home to England, returning to the colony in time to meet his wool on its arrival at the port of shipment, so long and tedious was the journey. Drays and impromptu slides had to be made; creeks and rivers to be crossed; droughts killed off the bullocks for want of feed and water; floods converted the banks of rivers, etc., into 'tented fields' populated by drivers, whose rations often ran low; bush fires menaced the safety of the men, cattle, and freight, besides the occasional attacks by natives; in short, wool, while in transit from the far-back stations to the seaport, had an adventurous and risky career. There have been instances of two different years' clips being on the road at the same time."

Freight rate from Sydney to London is from about 75 cents a hundred pounds by sailing vessel to $1.25 to $2 a hundred pounds by steamer.

Nearly all the wool sold in Australia is disposed of by auction to the highest bidder at the principal colonial markets. These sales have grown in popular favor and importance, having amounted to 697,705

bales for the season of 1891–92 for all the colonies. For that season 42 per cent. of all the sales were effected at Melbourne and Geelong, and 40 per cent. at Sydney.

The chief and almost only increase in the world's production of wool is in Australia. For the ten years ending with 1892 the wool production of Cape of Good Hope increased about 36,000,000 pounds; that of the Argentine Republic about 66,000,000 pounds; and that of North America about 13,000,000 pounds — in all about 115,000,000 pounds; while that of Australia increased about 278,000,000 pounds, or over 70 per cent. of the total increase. These figures are based on the imports of wool into Europe and North America, where they are alone manufactured and where they are wholly shipped. Practically the wool production of the world seems to be stationary or on the decline in all wool-producing countries except Australia. Nearly 30 per cent. of all the wool consumed is from the flocks of Australasia, and this proportion is increasing every year.

I had been in hopes of presenting in this paper some of the results of the scientific experiments that have been conducted under the supervision of Dr. William McMurtrie, affecting the wools at the World's Fair, but they are not yet ready for publication.

THE WOOD ARCHITECTURE OF SWITZERLAND.

By WILLIAM DANMAR.

Read March 22, 1894.

THE architecture of the farmhouse, where it is still historical and true, belongs as well to the history of art as the folk-song does to the history of music. Not only the folk-songs and folk-costumes of the Swiss people, but also their peculiar wood architecture, as represented by their farmhouses, cottages, or *chalets*, and similar buildings, is acknowledged to be of great poetical and artistic value. The Swiss wood style, with its high constructive and decorative development and its picturesque effect, has secured for itself an honorable chapter in the history of architecture; it has, indeed, become the model style for wooden buildings, for even in its most elaborate ornamentations it never is contrary to the nature of wood as the material.

The study of this wood architecture is the more important for us because wood has always been and is still the great building material of America; more than 80 per cent. of our buildings consist of wood. But the style of our wooden buildings belongs to the Renaissance, or the new-birth of Greco-Roman architecture, which was a stone architecture. The art forms or trimmings of our frame houses, consisting of wood and paint, imitate the detail forms of stone buildings, trying to make us believe that they consist of marble or stone. Yet of real art we expect truth; this truth we find with the Swiss houses. Their style is the pure expression of their constructive and material nature; their form and color say distinctly these houses are built of wood! The Swiss style is just as much the model style for wooden buildings as the Greek and the Gothic; each in its way is a classical or model style for stone buildings.

There are two ways of classifying the Swiss houses — either by cantons, because each of them has its peculiarities in the style, or

by methods of construction. From the professional standpoint the latter classification is preferable; and therefore we shall consider, first, the "stile and rail buildings" of the flat lands; second, the "post and plank buildings" of the middle lands; and third, the block buildings of the high lands.

The Manneberg Mill near Effretikon (Figure 1), in the canton of Zurich, is a good representative of the stile and rail buildings. It stands isolated at the foot of a wooded slope of the Manneberg Mountain, which casts its shadow on the building. It is no longer used as a flour mill. An inscription states that this building was erected in the year 1675. The unsymmetrical arrangement of doors and windows in the gable front was necessitated by the ground plan, and looks quite interesting. The wooden framework is of a red-brown color, and contrasts beautifully with the white masonwork of the walls. Besides these two colors, there are yellow and green on the windows and shutters. The basements of nearly all Swiss houses have walls of plastered masonwork, made of broken stones and good mortar. The upper walls of this building belong to the class of Swiss stile and rail buildings; they are framed of red pine upright stiles or posts, level rails and inclined braces, all put together with mortise, tenon, and wooden pins. The open panels of the framework are filled with stone masonry, plastered and whitewashed. The timber forms the frame for the masonwork, and therefore these buildings are often termed "frame houses," though in this country we mean another method of building by that term. The windows of the Swiss houses are peculiar; since many are required to light the deep rooms with the low ceilings, they are placed alongside each other, or coupled, and therefore are termed couple windows. These windows are provided with outside sliding shutters, which slide either upward, sideward, or downward. These shutters, which are often beautifully decorated, form a very characteristic and pretty feature of Swiss architecture, and add much to the picturesque appearance of the Swiss houses.

The stile and rail buildings of the flat lands represent the latest method of Swiss building, and were invented to save wood, because in the flat lands wood has become quite expensive, while in the high lands there is still plenty of it. The stile and rail method has also been extensively applied in Germany, England, and other countries, for it is a simple, economical, and durable method of building, and always looks very pretty; yet it is a Swiss style, for it originated in Switzerland.

FIGURE 1. MANNEBERG MILL, NEAR EFFRETIKON, CANTON ZURICH.

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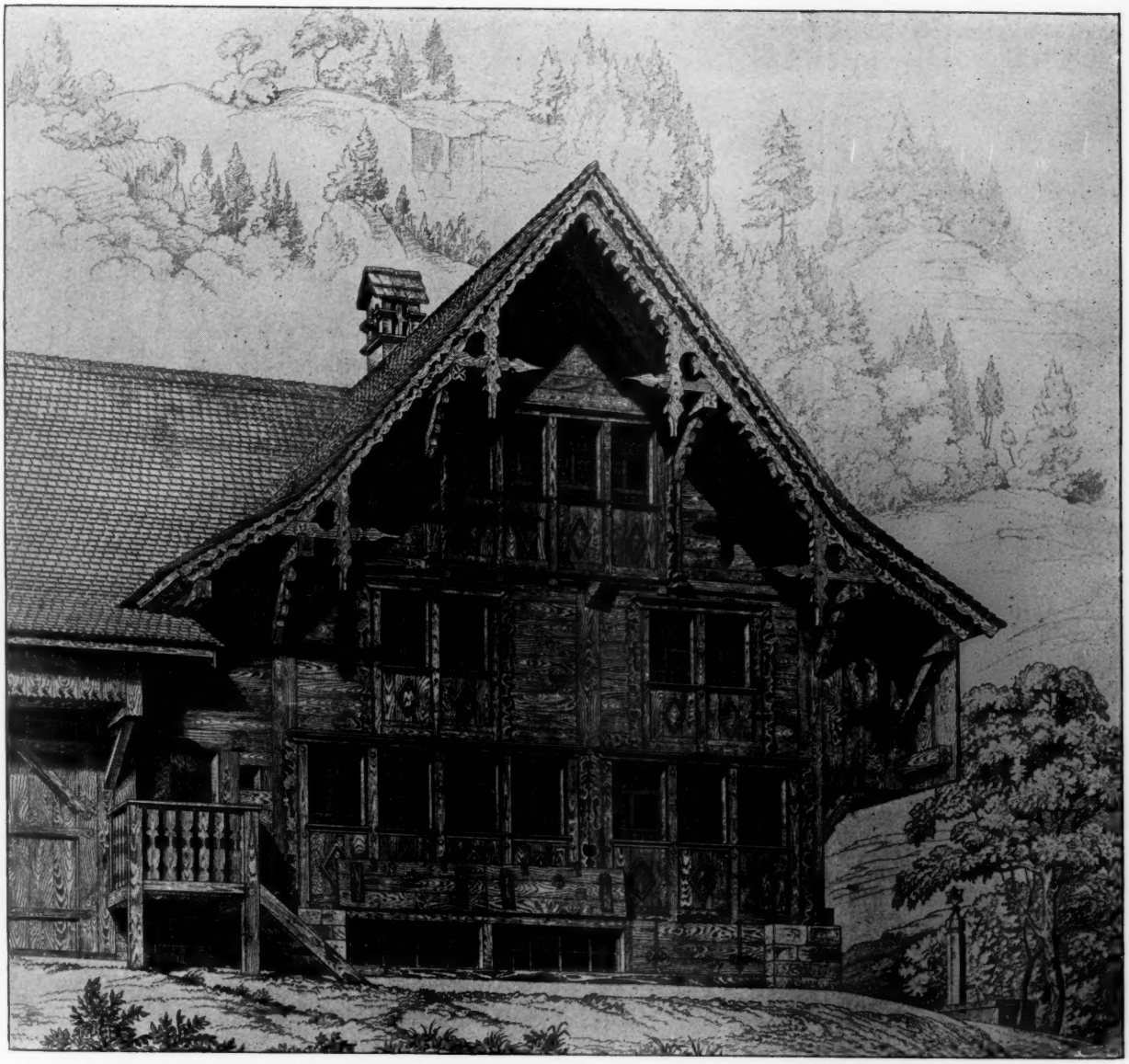

FIGURE 2. FARMHOUSE "ROSSWIESLI," CANTON ZURICH.

FIGURE 3. HOUSE OF CASPAR SCHILD, MEIRINGEN, CANTON BERN.

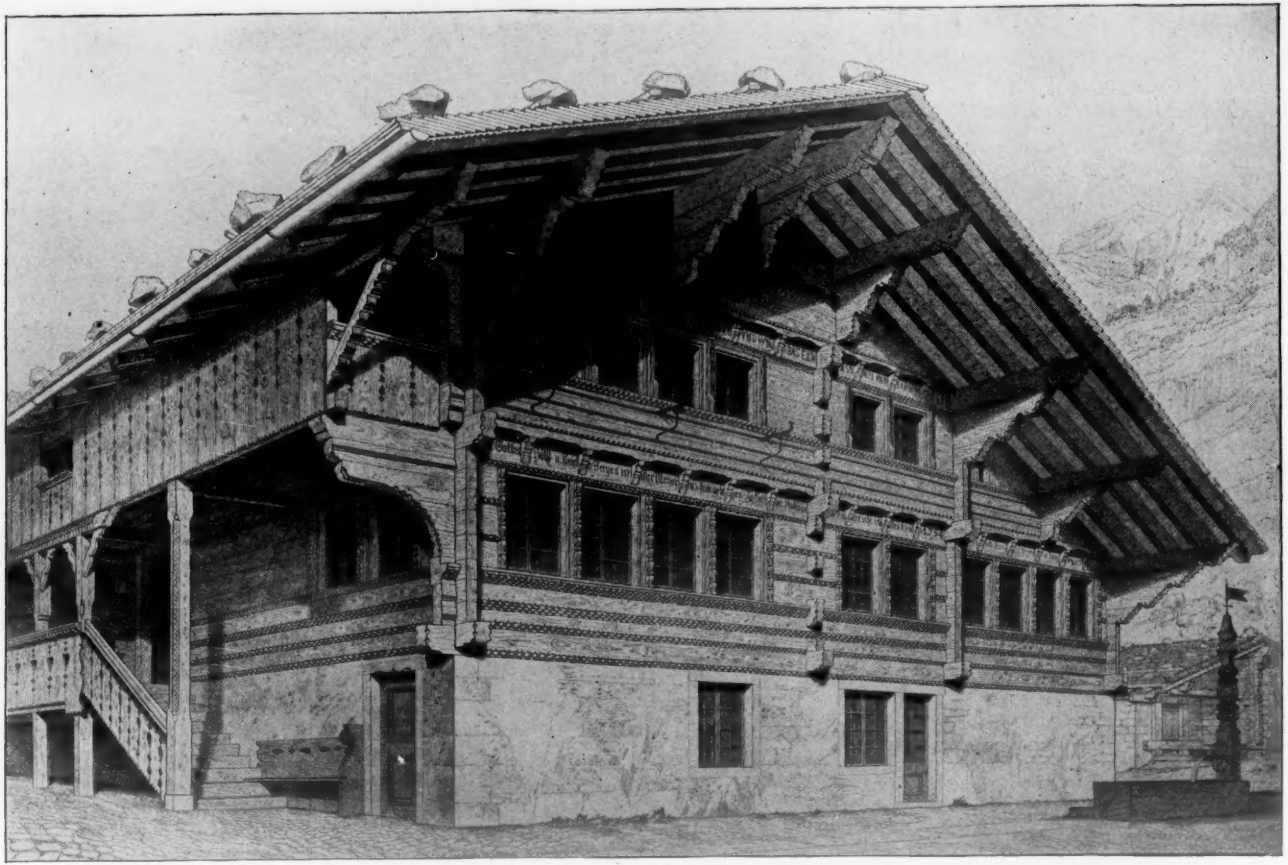

FIGURE 3. HOUSE OF CASPAR SCHILD, MEIRINGEN, CANTON BERN.

The second class of Swiss buildings are the posts and plank buildings of the middle lands. The farmhouse "Rosswiesli," in the Fish Valley of the canton of Zurich (Figure 2), is a fine representative of these buildings. It was built in the year 1785. Attached to the dwelling house are the farm buildings, stables, etc. This house is admired for its fine proportions and simple construction. The grooved posts and a few rails form the frame for the level planks, which in this case are flush with the posts and fastened to the same with half their thickness tenoned in the grooves of the posts. The purlins of the roof extend under the projections at the gables, and are there assisted by the peculiar Swiss gable brackets, which originated with the post and plank buildings and were also adopted for the stile and rail buildings.

The post and plank style is supposed to have originated in ancient times as an Alemannic method of building, and is still practiced to-day in the middle lands of Switzerland and Bavaria. The outside walls are often richly ornamented with painted escutcheons of the cantons, white stripes with carved or painted inscriptions, and decorated sliding shutters. Otherwise, these houses, as well as the blockhouses, are never painted, and through the influence of the weather their outer surface has received an appearance much like that of red-brown velvet, reflecting the light of the sun and adding much to their picturesque appearance.

The third and oldest class of Swiss buildings are the block buildings of the high lands. This method of building is older than history. Our original forefathers, the Aryans, when still living in the mountains of Asia, were building their houses in the manner of blockhouses, and all through the ages the mountaineers have maintained that architecture to the present day. It reached its highest development in the mountains of Switzerland, where there is still an abundance of heavy red pine timber, the transportation of which down the mountains to the market does not pay; in fact, in many cases is almost impossible. The house of Caspar Schild in Meiringen (Figure 3), in the canton of Bern, built in the year 1615, gives us an idea of the construction of the block buildings. The timbers are dressed on all four sides, and at the corners are notched and knotted together, showing two piers of projecting heads of block timber. These piers of block heads grow to large consoles or brackets, which carry the part of the roof which protects the gable walls; the brackets are often cut to an ornamental

shape, and form a great feature of this architecture. The few upright timbers at the doors and windows are mortised into the block timbers, with a leeway for settling. The shrinkage of wood amounts to about $2\frac{1}{2}$ per cent. of its thickness, and since there is nothing in the construction of these buildings to hinder them from settling that much, all joints remain tight, which is one of the secrets why these buildings last so long. The interior walls are made in the same way; they either show the smooth surface of the block timber or are covered with wainscot, which often shows beautiful panels with inlaid work of different woods. The ceilings and floors are formed by matched planks about 4 inches thick, which rest on the walls, and in large rooms also, on one intermediate girder. These planks form the ceiling for the lower and the floor for the upper story. This method of Swiss floor building was the origin of the slow-burning mill construction, which is now extensively applied in this country for mills and factories.

The wide, overhanging roofs of the block buildings are loaded with heavy stones, held there by laths on top of the split shingles. The weight of these stones keeps the roofs on the buildings when the heavy winds of the high lands are taking hold of their large projections. The original Swiss blockhouses have no interior halls or corridors, but, instead of them, outside stairs and passages which lead to the different apartments. The galleries ("Lauben," covered passages), form another picturesque feature of the Swiss houses.

There has been a good deal said about the artistic feelings of the mountaineers who build their houses so squatty and the roofs so broad, to contrast effectively with the steep mountains, and thereby obtain a good effect. But if we study these buildings from the standpoint of the practical constructor, we must come to the conclusion that the mountaineers never thought of such an effect, but simply built as necessity through the many centuries taught them to build to obtain a cozy and lasting home; and it is just the unintended and unpretentious picturesqueness of the Swiss houses and their surroundings which makes them so attractive to the artists.

The Swiss buildings of all the three above described classes belong to the purest forms of architecture; they have decidedly a style of their own, and that style is not an artificial mask, a covering *façade*, but it is the natural outgrowth of the construction itself. There is no shabby imitation of stone architecture on these buildings, but they are

true to themselves and entirely without pretensions to anything that is not really due to them. Their outside tells the true story of their construction, and nothing else. Thus their truthfulness harmonizes so beautifully with surrounding nature and makes them so immensely picturesque.

It was very natural for the first settlers in America to imitate the buildings of the countries they came from. The colonial style of this country has developed through such imitation, and really represents the best adaptation of Renaissance architecture to wooden buildings, but still it imitates stone architecture. The wooden cottages without much trimming, but composed of stained or bleached shingle work, show a movement in the direction of true wood architecture.

The Swiss style is but little known and applied in this country. Its study and introduction would undoubtedly improve our cottage architecture not only from the constructive but also from the artistic point of view. We need not copy the Swiss buildings, but may maintain our method of weather boarding; yet there are these points which we could profitably accept of the Swiss styles: first, the wide, overhanging roofs, which protect the woodwork of the walls against the rain, so that the Swiss houses last from four to five centuries, while our frame houses, with their Renaissance cornices which give no such protection to the walls, last but one to one and a half centuries; second, the method of detailing and trimming in accordance with the true nature of wood, for which the Swiss styles offer us the elemental forms from which, in adaptation to our needs, methods, and materials, an American wood style of architecture could be developed.

In fact, if we adopt the wide roofs only, then a wood style will follow, because the large projections of the roofs, which in Switzerland amount to from 6 to 10 feet, require for their support an exterior timbering with the appearance of wood construction. The usefulness of such roofs has never been so strongly impressed on me as through the study of colonial architecture in New England. All the Puritan meeting houses of the seventeenth century have rotted away, except the Unitarian Church at Hingham, the "Old Ship," built in 1685, which has been preserved only by renewing all the exterior woodwork twice and taking the best care of it. There are a few cottages left of the seventeenth century, but they are really ruins; and neither is there much left of the wooden buildings of the first half of the eighteenth century. Soon colonial architecture will be entirely wiped out

by the weather, because it has no umbrellas when it rains, and the umbrellas are missing because it imitates stone architecture, which has no need for them.

The true spirit of art is opposed to all imitation; therefore, if we would be willing to learn of the Swiss builders, we should cease to imitate stone architecture; we should return to nature and truth, and make it appear in the exterior of our wooden buildings that they consist of wood and nothing but wood.

A CLASSIFICATION OF ECONOMIC GEOLOGICAL DEPOSITS, BASED ON ORIGIN AND ORIGINAL STRUCTURE.

By W. O. CROSBY.

Received February 20, 1894.

INTRODUCTION.

The title of this paper might be otherwise expressed as the enumeration and brief description in natural order of the various modes of origin and occurrence of useful minerals and rocks. A strictly natural classification on economic lines is, of course, impossible, simply because nature has shown no special regard for our economic distinctions. The position of a rock in the natural classification is essentially the same, whether it contains one grain, one ounce, or one pound of gold to the ton. The economic classification must in every instance be a fragmentary scheme, lacking the completeness and perfect coördination or symmetry which we recognize or believe to be recognizable in nature; for it represents a body of knowledge having arbitrary or artificial and shifting boundaries. A mineral which is valueless to-day may find a useful application to-morrow, and thus, perhaps, introduce into the economic classification a new type of deposit; and in like manner the deposits of a particular type may be dropped from the economic scheme if the substance which they afford be supplanted in its relations to human welfare by some other. The most nearly ideal plan would, it is believed, be a completely elaborated natural or scientific classification, with a special mark to designate those deposits of present economic interest. The practical man, who often cares little for the general relations to the whole of the small part in which he feels a vital interest, might be disposed to criticise such a classification as unnecessarily complicated and as implying a more extended knowledge of general geology than he usually possesses; but for the teacher and

the student of economic geology, and all who care for broad views over this field, it would possess obvious advantages.

It is generally conceded that, whatever the limits of the classification, its highest value, both as a means of education and as an aid in the discovery and exploitation of deposits, demands that it should be essentially geological, and not be based, at least in its main lines, upon the qualities or uses of the materials. Now geology is first of all a dynamical science, and, as Professor Kemp has shown,[1] there are cogent reasons for basing a classification of economic deposits upon origin instead of structure. The genetic principle so universally recognized as the basis or key-note of biologic classifications is slowly but surely making its way in the domain of geology. Classification by structure, of which form is but the external expression, is less difficult, and hence has generally prevailed in the early days of each science. The main reason why the recognition of the genetic principle has made relatively so little progress in geology is that the processes, being to a large degree chemical, are often exceedingly obscure; and the correct interpretation of the observed facts of composition and structure is hence peculiarly difficult. Our knowledge is, in consequence, decidedly insufficient in certain directions for the detailed application of this principle of classification. It is, for example, the general belief of geologists that mineral veins have been formed chemically, that is, by the deposition of minerals from solution; but farther than that, as a rule, we cannot safely go, for the nature of the chemical process in particular cases is still a matter of speculation rather than of positive knowledge. The recent literature of the science shows, however, that light is breaking upon this problem in various directions, and we may hope for a better state of things in the near future.

It appears, then, that while differences of structure and composition must always be recognized in our classifications, they will become relatively less important with increasing knowledge of genetic processes. In this connection we may properly draw a sharp distinction between original and subsequent structures, the former alone having classificatory value. The validity of this distinction is apparent on referring to the biologic sciences, since, for example, the accidental loss of one or more of its rays by a starfish does not affect its position

[1] Ore Deposits of the United States, p. 42.

in the classification. Of course changes in geologic deposits amounting to complete metamorphism, to the transformation of one type into another, are truly original and genetic and not in any sense accidental with reference to the new type. Thus superficial oxidation may be neglected in the classification of veins, but it is highly important as defining one type of residual deposits. Distinctions based directly upon composition should be subordinate, in the main, to original structural distinctions, and hence can be generally recognized only in a more complete and detailed classification than is possible in the present state of our knowledge. Even a classification based upon origin and original structure, such as is attempted here, is necessarily in advance of our knowledge, in the sense that future investigations, in many cases, must decide to which sections particular deposits should be referred.

Many classifications of ore deposits have been published, and the more important of these have been recently summarized and compared by Professor Kemp in the introduction to his valuable work on the ore deposits of the United States. But, since the metalliferous minerals or ores constitute simply one limited division of the whole field of economic geology, it is apparent at a glance, after what precedes, that these classifications must be, without exception, seriously lacking in scientific and educational value. They may be said, perhaps, to meet in some degree the needs of the metallurgist and in a measure, also, those of the miner. But coal and many other nonmetalliferous minerals are extensively mined, and occur in characteristic deposits with the forms and modes of origin of which the miner should be acquainted.

The distinction of rocks (igneous and sedimentary formations) and mineral deposits (veins, impregnations, etc.), or, as it is commonly stated, original and secondary deposits, or unconcentrated and concentrated mineral deposits, is deemed of great importance by some authorities, and notably, among the more recent writers, by Posepny, who has introduced the terms idiogenous and xenogenous to designate these two classes. It seems to the present writer, however, that in a broad view of the field this distinction largely disappears or becomes of subordinate importance.

Strictly speaking, nearly all, if not quite all, known rocks are secondary. This is generally conceded for the sedimentary rocks; but, following Iddings and other recent writers, it must be admitted also for the igneous rocks. A dike is a more or less highly differentiated

portion of some deep-seated *magma*, and it is clearly newer than the walls. An ascensionist, certainly, can say nothing more for a vein save that while in the formation of the dike heat is the chief agent, with water coöperating (aqueo-igneous fusion); in the formation of the vein water is the chief agent, with heat coöperating (igneo-aqueous solution). The greater mobility of the solution permits a higher degree of concentration, but concentration is a universal process and participates in the formation of eruptive masses and sedimentary deposits as well as of veins. In other words, solidification and deposition, or the rock-making processes, involve in every instance differentiation and concentration; while liquefaction, or the destruction of rocks, whether aqueous or igneous, implies just as universally the undoing of differentiation, or dissipation of matter. It appears illogical, therefore, to regard one class of rocks (vein rocks) as fundamentally distinguished by the fact that their formation involves the concentration of their component minerals. The concentration is quite as marked in the formation of a bed of sand, clay, limestone, gypsum, chert, or iron ore; and, if less marked, it is certainly not less true, in the formation of a dike of granite or trap. In the opinion of the writer, no sharp line of demarcation can be drawn between dikes and veins, and veins are clearly entitled to some degree of recognition in the lithological classification. In a broad view of the early history of the earth, all the sedimentary and vein rocks are, of course, secondary with reference to the primitive igneous crust, but so are the igneous rocks with which we are now acquainted. Probably none of the igneous rocks which have been studied are truly primitive, and their derivation in some cases from sediments is claimed by many able observers.

Veins and dikes are newer than both walls; lava-flows and sedimentary strata are newer, always, than one wall and older than the other. But, for the reasons already stated, the primary distinctions should be genetic rather than structural, although here, as generally, a close correlation of genesis and structure is to be noted. Heat and water are the two great agents concerned in the modification and differentiation of the earth's crust; and they are generally, if not everywhere and always, in coöperation, heat prevailing, as a rule, at great depths and water at the surface. Thus arise the two principal classes of rocks — igneous and aqueous. In either class the rocks may be deep-seated (newer than both walls) or superficial (newer than one

wall), in other words, intrusive or contemporaneous. The intrusive igneous masses are known as dikes, etc., and the contemporaneous as lava-flows; while the intrusive aqueous masses are known as veins, etc., and the contemporaneous as sedimentary strata.

Subterranean aqueous deposition must always take place from solution, or in a purely chemical manner; but superficial aqueous deposition may take place from suspension (mechanically), or from solution (chemically), or through the agency of organic matter (organically); and these are undoubtedly, as generally recognized, the natural subdivisions of the superficial aqueous rocks, standing secondary to the distinction of superficial and deep-seated deposits. In several published classifications of ore deposits, however, the primary divisions of the aqueous deposits are based upon the essential nature of the formative process, whether mechanical or chemical. In other words, the first question asked concerning any type is, Was it deposited from suspension or solution? and not, Was it, in its origin, superficial or deep-seated? The disadvantage of this plan becomes apparent as soon as it is extended to embrace all economic deposits or to have approximately natural boundaries, for it associates deposits having little in common and dissociates those that are closely related. Thus a bed of gypsum and a vein or impregnation, say of tin ore, are, according to these classifications, more nearly related, since both are chemical deposits, than a bed of gypsum and a bed of slate. This may be true from the standpoint of a chemist, but it is certainly not good geology; for whether we are considering the relations of the deposits to each other or their general relations to geological history, gypsum stands naturally much nearer to slate than to tin ore; and genetic, structural, and economic considerations all demand that superficial and deep-seated deposits should not be commingled.

In the opinion of the writer we have good reason to believe that fusion and solution are not only continuous and overlapping processes, but that giant granite or pegmatite may be regarded as marking the halfway point, the product of their perfect coöperation. Pegmatite combines the characters of plutonic and vein rocks, but does not belong distinctly to either class, demanding separate recognition and classification.

EXPLANATION OF THE CLASSIFICATION.

The classification embraces, as the table shows, three primary and coördinate divisions, as follows:

A. Deposits of igneous origin (igneous rocks). Heat is the chief agent.

B. Deposits of aqueo-igneous origin (giant granite or pegmatite). Heat and water coöperate.

C. Deposits of aqueous origin (sedimentary and vein rocks). Water is the chief agent.

These main divisions of the classification may now be considered separately, and their subdivisions noted, with illustrative examples of each type, so far as such have been clearly recognized. Many of the examples, it should be added, have been taken directly from Professor Kemp's *Ore Deposits of the United States;* and his interpretations of the facts have, in most cases, been accepted without further investigation.

A. Deposits of igneous origin. — Following the lines of the lithological classification, we may divide the igneous rocks into the intrusive or plutonic rocks and the extrusive or volcanic rocks, although this distinction is obviously not of paramount importance on purely economic grounds. These two great classes of igneous rocks admit, for economic purposes, of parallel subdivision, as follows:

I. Igneous deposits of subterranean origin (plutonic rocks). — Among the plutonic rocks we may recognize:

(*a*) *Normal plutonic rocks*, altered and unaltered. These are useful especially as affording materials for construction (building and ornamental stones, etc.), but they have in the aggregate, by virtue of their abrasive, refractory, and other qualities, a wide range of applications in the arts.

(*b*) *Highly differentiated and excessively basic plutonic rocks.* These are peridotites and other ultra-basic rocks, in which, through the operation, we may suppose, of Soret's principle, as Iddings[1] insists, aided, possibly, by magnetism and gravitation, as suggested by Vogt,[2] the metallic oxides or free bases (magnetite, menaccanite, etc.), which

[1] Bulletin Phil. Soc. of Washington, 12, 158.

[2] Geol. Fören. i. Stockholm-Förhand, 13, 476, May, 1891. English abstract and review by J. J. H. Teall, Geological Magazine, February, 1892.

occur only as relatively unimportant accessories in the normal types, become highly concentrated and give character to the rock, constituting a very distinct and not unimportant type of iron ore. The dike or stock of titaniferous magnetite, with accessory olivine and feldspar, of Cumberland, Rhode Island, is a good example, and these ores have also been recognized in the Adirondacks, Minnesota, Brazil, and Scandinavia. It appears, in fact, that the highly titaniferous crystalline iron ores should be in general referred to this type.

(*c*) *Original disseminations in plutonic rocks.* Not the rock as a whole but a single original constituent is useful. The useful mineral may be an accessory, as the zircon in certain syenites, or essential, as the chatoyant labradorite of certain norites and gabbros. This type is not markedly different from the preceding (*b*). Only one constituent or class of constituents is, strictly speaking, useful in each case; but the magmatic concentration is an essential feature of (*b*), and the entire rock or ore must be mined and submitted to, metallurgical treatment. The last consideration savors somewhat of a classification by uses, and the chief emphasis should, therefore, be laid upon the concentration of (*b*) as the more essential distinction.

Each of these three types (*a*, *b*, *c*) may, theoretically, at least, occur in or form (1) dikes, (2) intrusive sheets or sills, (3) laccolites, (4) stocks or plugs, bosses, and complexes.

(*d*) *Sublimates* formed in dry fissures or other cavities, and not necessarily in plutonic rocks, although heat, of course, is still the chief agent. This type — virtually veins formed by sublimation — is proposed with hesitation. Sublimation is at the present time, and justly, in marked disfavor as a general explanation of mineral veins. Below the permanent water level the vacant fissures essential to the formation of sublimates must be nonexistent, and subterranean sublimation deposits, if occurring at all, must be quite limited in depth, while the composition and structure of most veins are best explained by deposition from solution. On the other hand, the varied and abundant sublimates formed on the surfaces and in the cracks of recent lavas make it more than probable that, at least in the neighborhood of volcanic vents, they extend to a sufficient depth to deserve classification among subterranean deposits, and we may safely conclude that sublimation is a true, though not a principal, cause of vein formation. This conclusion is sustained by the fact that a large proportion of the vein-forming minerals have been produced experimentally by sublima-

tion. Although accepting the sublimation theory as a valid explanation within the narrow limits indicated, I am unable to cite positively any economic deposits as examples under this head, but there seems to be a fair probability that such exist.

II. Igneous deposits of superficial origin (volcanic rocks).— Similarly, the volcanic rocks include:

(*a*) *Normal volcanic rocks or lavas* (including *tuffs*), ancient and modern. These, like the corresponding plutonic rocks, are useful chiefly for structural purposes, but it is sufficient to cite pumice to indicate that they also have other uses.

(*b*) *Highly differentiated and excessively basic volcanic rocks.* The conditions are undoubtedly less favorable for the development of the igneous iron ores in lava-flows than in plutonic masses, but this type is proposed in the belief that this mode of occurrence is not impossible. In fact, it might almost be claimed that we have an example in the huge masses of native iron in the basalt of Ovifak.

(*c*) *Original disseminations in volcanic rocks.* The crystals of peridot (olivine) and various other gems occurring as original, and usually as accessory, constituents of lavas clearly justify this feature of the classification.

Each of these three types (*a*, *b*, *c*) may occur in or form (1) contemporaneous sheets or flows, (2) volcanic cones, (3) volcanic pipes or necks.

(*d*) *Sublimates* on recent lava in solfataras, fumaroles, etc. The abundant occurrence of sulphur, boracic acid, and other minerals of economic interest in and about volcanic craters, establishes the validity of this type.

B. Deposits of aqueo-igneous origin.—The arguments for the separate recognition in the lithological classification of the aqueo-igneous rocks, or pegmatites, have been stated with sufficient fullness. Their economic importance is manifest when we reflect that they are the principal source of quartz, feldspar, and mica for commercial purposes, that they contain important deposits of tin ore, and that they afford tourmaline, beryl, and other valuable gems.

C. Deposits of aqueous origin. — The aqueous deposits embrace, as already explained, both those of subterranean origin (vein rocks, etc.) and those of superficial origin (sedimentary rocks, etc.).

I. Aqueous deposits of subterranean origin (vein rocks, etc.). — These have necessarily been formed by deposition from solution; but, although they are, in general, vein-like, and are, as a class, commonly called veins, it appears to the writer that in a classification based upon origin three main divisions should be recognized, as follows: veins, or deposits in preëxisting cavities; impregnations, both metasomatic and non-metasomatic; and substitution deposits, or complete metasomatic replacements.

1. Veins, or deposits in preëxisting cavities.—The line of demarcation between impregnations and substitution deposits is, in the nature of the case, less sharply defined than that between either of these classes and veins, since metasomatic impregnations must grade into complete replacements. A preëxisting cavity, or free, continuous space, is regarded as essential to the formation of a vein, and all deposits in such cavities, without regard to the forms or modes of origin of the cavities, are here classed and described as veins. It should be noted, however, that the cavities are usually, if not always, secondary features of the wall-rock, the product, in general, of displacement, plication, shrinkage, or solution. The only important instance, so far as I know, of cavities contemporaneous with the walls which might conceivably become the seats of veins is afforded by the lava tunnels, which are a somewhat important feature of the Hawaiian and some other volcanoes. It seems extremely probable that cavities formed in this way have, in some instances, been filled by deposition from solution; but, so far as I am aware, this mode of occurrence has not been demonstrated, at least not for any economic deposits, although it is well known that the "chimney" form which this origin would require has been clearly recognized in certain ore deposits. The discovery of an undoubted instance of such a lava-tunnel vein of economic interest would necessitate a fundamental distinction between veins filling original and those filling secondary cavities, all the types of veins recognized in this paper belonging to the second class.

True veins are, of course, always to be reckoned as structural rather than textural features of the formations which they traverse, and the amygdaloidal and interstitial deposits due to the filling of steam holes and other forms of interstices are types of impregnations and not of veins. It may be noted, however, that the larger steam-holes pass gradually into irregular cavities of considerable size which

are also often filled with segregations of chalcedony, etc., and clearly point to the possibility of veins in lava tunnels.

The following classification of veins formed in secondary cavities is based upon the modes of origin, and only incidentally upon the forms of the cavities or fissures; but it is clearly recognized, as already pointed out, that with increasing knowledge of the chemistry of vein formation the mode of filling will take precedence as a basis for the classification, the present arrangement being regarded as provisional. Not only the character of the mineral solutions, but their sources, whether descending, lateral (lateral secretion veins), or ascending, should be considered in the true classification of veins. The advocate of either source to the exclusion of the others ought to appear as archaic now as would an out and out plutonist or neptunist; for this is the day of the recognition of the kernel of truth in every theory. We are recognizing more and more clearly that nature has worked in diverse modes to the same general end, and that a complex class of phenomena cannot, as a rule, be referred to a single simple cause. Posepny has properly emphasized the distinction between the superficial and the deep-seated aqueous circulation; and he is undoubtedly right in relegating the phenomena of vein formation chiefly to the domain of the latter. But in his enthusiasm as an ascensionist he has probably gone too far and referred to ascending currents deposits that may be more readily explained by lateral secretion or descending currents.

During the filling of a cavity the mineral solutions may or may not penetrate and impregnate the walls; and this impregnation, when it occurs, may or may not be metasomatic. Thus the same continuous deposit may combine a vein and an impregnation, or a vein and a substitution deposit, or all three; and the vein is in many cases the least important part of the combination, having simply supplied a channel for the impregnating and replacing solutions. Similarly veins may or may not occur on or near igneous contacts, although, as others have pointed out, all deep veins are contact deposits with reference to the igneous interior of the earth. These distinctions, as well as the source and nature of the solutions and the mode of origin of the cavities, should be recognized in a complete and detailed classification of veins. But it is deemed sufficient to simply refer to them here, and thus, incidentally, to explain the absence from the outline scheme here proposed of the so-called contact veins.

In a classification of veins filling secondary cavities, in accordance with the mode of origin of the cavities, it is of the first importance to distinguish sharply, as Posepny has done, between the cavities formed by mechanical forces ("spaces of discission") and those formed by chemical forces ("spaces of dissolution"). Of the eight types of veins described in the following pages, six belong to the first category and two to the second.

(*a*) *True fissure veins*, filling profound fissures, which are usually accompanied by displacement (fault-fissures). This is the leading type of veins and is so recognized in the standard text-books of geology. When the fissures can be proved to coincide with important displacements, permanence in depth is reasonably assured and filling by ascending currents may be regarded as highly probable. Slickensided walls and a distinct selvage are very characteristic features, though by no means essential or peculiar. Important examples are so numerous as to make citation or further description unnecessary.

(*b*) *Crushed-zone or shear veins*, filling crushed or shear zones along faults or lines of shearing stress. These are often equivalent to fissure veins filled with fragments of the wall-rock; and in other cases the crushing may take the form of a more or less distinct sheeting. The crushed or sheeted rock is frequently extensively impregnated or replaced by the vein matter; and the inclosure of the fragments is often so dike-like that the vein matter has, even by some recent writers, been regarded as of igneous origin. The veins of this type are commonly without definite boundaries or walls and sometimes pass into more or less typical stockworks. The normal form of the deposit, when not sheeted, is believed to be approximately or roughly lenticular, and it is probable that one great lens may succeed another in strike or depth along an extended line of fracture. This localization of the crushing may, apparently, be regarded as a necessary result of a shearing stress along a highly irregular or somewhat interlocking fracture, the protruding or convex portions only of either wall being crushed by the enormous friction. Among the more important deposits believed to be referable to this type are the nickel ores of the Sudbury District, Ontario, and the Gap Mine, Pennsylvania.

(*c*) *Joint or gash veins*, filling joint-cracks, or fissures due to (1) shrinkage and (2) vibratory and torsional strains, and (3) transverse fissures due to plication and warping, without faulting. This type, with varying definition, has been recognized in several classifica-

tions of veins. It is, of course, not always sharply distinguished from the true fissure veins. The chief points of difference are that faulting is more commonly absent and when occurring is less extensive, that the veins are more limited in length and depth, that slickensided walls and a true selvage are more commonly wanting, and the filling is more likely to have been by lateral secretion. Like joint-cracks, the gash veins are frequently intersecting (reticulated veins) and often exhibit the stockwork phase. In fact, reticulated veins and veinlets, or stockworks, although a phase, also, of shear veins, may be regarded as in the main a sub-type of the gash veins. In calcareous rocks the cracks have been very generally enlarged by solution before filling; and in both calcareous and siliceous rocks impregnation and replacement of the walls are of common occurrence. The transverse fissures due to plication, here referred to the gash veins, are likely to be limited in depth and to differ from ordinary joint-cracks chiefly in the divergence of the walls, diverging downwards in synclinal cracks and upwards in anticlinal cracks. Among the many more or less typical examples of gash veins which might be cited are the following: The auriferous pyrite and chalcopyrite veins of Gilpin County, Colorado; the veinlets of native copper in felsite, Santa Rita, New Mexico; and the lead and zinc deposits of the Mississippi Valley, which take the form chiefly of gash veins and flats, the flats being in part horizontal gash veins. As examples of stockworks in this country we have: the Black Copper group, Globe District, Arizona; the zinc deposits of Saucon Valley, Pennsylvania; the lead-silver deposits in the dolomite of Aspen Mountain, Colorado; and in part the quicksilver deposits of New Almaden, California.

(*d*) *Interbedded veins*, filling rifts between the strata, *i.e.*, fissures parallel with the strata and due to plication. Although the close relations of this type to the gash veins are very obvious, its distinctive features are so strongly marked as, in the opinion of the writer, to justify its separate recognition. In fact, no type of veins possesses more definite characteristics or is more readily identified. As a rule they conform closely or perfectly with the strata in strike and dip; present, in many cases, remarkably smooth and well-defined walls, without indications of slipping, and from the nature of the case they must be limited in depth. The essential thing is that they are rifts due to plication; for of course true fissure veins (*a*) may conform with the strata superficially. Tarr, in his recent and comprehensive

work on the *Economic Geology of the United States* (p. 90) seems to consider that for veins of this type there were no preëxisting fissures, segregation commencing along a bedding, cleavage, or joint plane, and the deposit, as it grew, crowding back the rocks and making room for itself, much as a concretion or a root would. That this is a possible explanation I am ready to believe, for I have observed something analogous in the veinlets of gypsum traversing anhydrite in the gypsum quarries of Windsor, Nova Scotia. But rifts between the strata are unquestionably a natural result of the folding of thin-bedded rocks; although the two causes might, of course, coöperate. If these truly concretionary veins should prove to be important or of economic interest, it would become necessary to make a fundamental distinction in the classification between endogenous veins (formed in preëxisting cavities) and exogenous veins (formed, like concretions, in the solid rock). As examples of interbedded veins we have the auriferous quartz veins of Nova Scotia, California, and other districts; the great lenticular veins of pyrite along the Appalachian belt; the lenses of specular hematite on the James River, Virginia; and, possibly, some of the great lenses and sheets of magnetite belong here.

(*e*) *Neck veins*, filling the interstices of agglomerates in volcanic pipes or necks. This is a recently, but now quite generally, recognized type, based upon the Bassick and Bull Domingo silver mines, near Rosita, Colorado. These ore bodies or deposits are chimneys, 20 to 100 and 40 to 60 feet in horizontal section, in andesite and in Archæan gneiss, respectively, filled chiefly with fragments of the wall-rock, and between, over, and replacing these fragments the deposition of the ores has taken place. This mode of occurrence is, *a priori*, so probable, that we may fairly suppose that other and more important examples have been overlooked or misinterpreted. The resemblance of this type to the lenticular crushed-zone or shear veins is quite marked; and when we consider that, as in these cases, the necks of craters and craterlets are naturally elliptical in outline and tend to occur in linear series along lines of fissure, the need of proceeding cautiously in distinguishing these two types is obvious.

(*f*) *Crenitic veins*, filling the conduits of thermal and other springs. This type, which, so far as I know, is proposed here for the first time, is suggested by the deposits of silver-lead ores of Red Mountain, Ouray County, Colorado. The deposits traverse the mountain in an irregular way, and are believed to mark the courses of old hot spring

conduits. The wall-rock is silicified andesite, having been highly altered by the ancient thermal waters. This type differs from true fissure veins much as a volcanic neck differs from a typical dike; *i.e.*, the ascending ore solutions are more localized, and it is, perhaps, possible that at greater depths these conduit deposits pass into normal fissure veins. Believing, as we do, that mineral springs have played an important part in the formation of veins, the only occasion for surprise is that these crenitic veins have not been more frequently identified and described; and it will be recalled that Sandberger finds here one of his chief arguments against the theory that veins are formed by ascending currents. It is probable that the conduits have, in most cases, at least, been somewhat enlarged and modified in form by solution prior to filling. This assumption would be particularly safe when the wall-rock is limestone, but such modification must, evidently, be equally common with gash veins and other types having the normal sheet form. The cavities of mechanical and of chemical origin are thus combined, but gradation and transition forms are the rule everywhere in geology, and veins are no exception.

(*g*) *Cavern veins* filling cavities due to solution, including chambers, flats, sheets, pitches, etc. This is the principal type of veins filling "spaces of dissolution." On *a priori* grounds it has strong claims to recognition. Solution cavities or caverns are numerous, especially in limestones above the drainage level; and we often observe them in process of filling, especially with stalactite and stalagmite deposits. The chief difficulty is to find undoubted examples of economic interest, nearly all the deposits formerly referred to this type having been proved, on more careful study, to be replacements. As more or less probable examples I may cite the celebrated Cave Mine of Beaver County, Utah; some of the lead and zinc deposits of the Mississippi Valley (enlarged gash veins); and a series of small caves near Ouray, Colorado, in quartzite overlain by shales, and containing native gold. The clearest and most unequivocal examples of all, however, we have in the deposits of onyx marble of stalactitic and stalagmitic origin in limestone caverns.

(*h*) *Brecciated cavern veins*, filling collapsed or brecciated beds resulting from solution, dolomitization, or some other chemical change. This type is related to the last very much as the shear veins are to the true fissure veins. Particular strata of limestone are weakened by the solvent action of percolating water; they collapse and become brecci-

ated, and between and around the fragments thus resulting the vein minerals are deposited. It is obvious that metasomatic replacements might not be readily distinguished from deposits of this type. Among the actual occurrences supposed to belong here are the specular hematite of Crawford County, Missouri; the copper ore of St. Genevieve, Missouri; the lead and zinc deposits of the Upper Mississippi Valley (in part), including the "lower flats" and "tumblers" of Chamberlain; and the zinc deposits of southwest Missouri.

2. Impregnations, or deposits filling the pores, and often replacing the original or normal constituents of various rocks (metasomatosis).— Although second only in importance to veins, this main type of aqueous deposits may be more briefly described. Certain types of impregnations occur chiefly, as already explained, in the walls of veins, the fissure having afforded a passage for the impregnating solutions in each case. Also, impregnations like veins may or may not occur along igneous contacts. In the subdivision of impregnations we may properly distinguish the concretionary, pore-filling but not concretionary, and metasomatic but not concretionary types, as follows:

(*a*) *Concretionary deposits that are not metasomatic — impure concretions*, due to the segregation of a soluble constituent in a siliceous or otherwise insoluble rock. The segregating minerals are chiefly carbonates (calcite, etc.), including the carbonate of iron from which the iron is often deposited as the insoluble oxides. Being unable to remove the siliceous matrix, the segregating minerals are deposited in it, more perfectly cementing the particles of clay, grains of sand, etc. The common clay-stone is a familiar example of these impure concretions — combinations of concretion and matrix — and clay ironstone may be named as the chief economic example.

(*b*) *Concretionary deposits that are metasomatic — pure concretions*, due to the segregation of a soluble constituent in a soluble or metasomatically replaceable matrix. The siliceous concretions of calcareous rocks (flint and chert nodules, geodes, etc.) are clearly the most important examples, and no more distinctly economic examples have occurred to me; but this type may fairly be retained to preserve the symmetry of the classification. It should be noted that the essential idea of an economic concretionary deposit is that, although the segregating mineral is an original constituent of the rock, the segregation is required to make it available (concrete) and useful. If the rock as a whole is useful, as in the case of oölitic limestone and iron ore, it

must be differently classified. Clay ironstone is separated from black-band ore in the classification simply because segregation is, in the first, essential to make the iron carbonate useful, to change it from a rock to an ore; and the ore only and not the entire rock is used.

(*c*) *Amygdaloidal deposits*, filling the pores (steam holes) of igneous (volcanic) rocks. This familiar type requires no detailed explanation. The most important example is, of course, the cupriferous amygdaloid of Keweenaw Point, to which may be added the cupriferous felsite of Santa Rita, New Mexico, although the supposed amygdules may be only pseudo-amygdules, or actual replacements, filling secondary cavities, which would refer the deposit to the metasomatic impregnations.

(*d*) *Interstitial deposits*, filling the pores (interstices) of sedimentary (chiefly fragmental) rocks. The designation of this type, although not, perhaps, wholly unobjectionable, is the most satisfactory that has occurred to the writer. It is intended to include all those cases where sedimentary rocks have been filled but not replaced by economic amounts of useful minerals. It is very probable, however, that in many cases, as in the cupriferous conglomerate of Keweenaw Point, the interstitial filling is accompanied by true metasomatic replacement. As additional examples of this type we have the cupriferous sandstones of the Copper Basin, etc., Arizona, and of various localities in Texas, New Mexico, Utah, etc.; the silver-lead, apparently non-metasomatic, deposit in quartzite of Coeur d'Alene, Idaho; the Potsdam sandstone of the Black Hills impregnated with auriferous pyrite, which may be oxidized; and the argentiferous Triassic sandstone of the celebrated Silver Reef Mine, Utah.

The non-concretionary metasomatic impregnations may be conveniently subdivided in accordance with the nature of the impregnated rock, as follows:

(*e*) *Metasomatic deposits in calcareous rocks.* The Clinton iron ores appear to be in part limestone replaced by ferric oxide. The deposits of galenite and nickeliferous pyrite of Bonne Terre, Mine la Motte, and Doe Run, Missouri, are local enrichments (impregnations) of limestone; and the silver ores of Glendale, Montana, and Wood River, Idaho, clearly belong under this type. According to Kemp's recent and able summary of our knowledge of the extensive and unique deposits of oxidized zinc ores at Franklin Furnace and

Ogdensburg, New Jersey, they are most probably interbedded impregnations.[1]

(*f*) *Metasomatic deposits in fragmental rocks.* Some of the native copper of Keweenaw Point belongs here; and the copper ores near the trap sheets in the Triassic sandstone of New Jersey not only impregnate, but, apparently, actually replace, the sandstone.

(*g*) *Metasomatic deposits in igneous rocks.* The first examples noted occur in volcanic rocks and the later ones in plutonic rocks. In the cupriferous amygdaloid of Keweenaw Point, the copper is in part a true replacement of the diabase.

The auriferous quartz of the Little Annie Mine, Rio Grande County, Colorado, is probably a silicified rhyolite. At Silver Cliff, Colorado, rhyolite is impregnated with cerargyrite; and in the Calico District of California liparite and tuff are similarly impregnated. The copper deposits of Llano County, Texas, are partly fissure veins, but chiefly true impregnations in granite. The copper ores of the Morenci District, Arizona, are in part impregnations of the porphyry in which they occur. Many of the gold and silver deposits of the Rocky Mountains, etc., are metasomatic impregnations of dikes and plutonic masses. The tin deposits of Irish Creek, Virginia, are typical impregnations of granite along leaders (veinlets) of quartz.

(*h*) *Metasomatic deposits in metamorphic rocks* (*gneisses and schists*). These deposits, when conforming with the bedding or foliation, constitute the typical *fahlbands*, and are then not easily distinguished from original sedimentary deposits on the one hand and interbedded veins on the other. Besides the classic example, the argentiferous fahlbands at Kongsberg, Norway, which are of economic interest only at their intersections with a series of veins, we may notice one important American locality. The great pyritiferous bed (superficially oxidized) of the Homestake Mine and other similar beds in the Black Hills are either original or secondary (true) fahlbands. If the pyrite is a part of the original sedimentary deposit, the subsequent changes — crystallization and segregation — have probably been sufficiently extensive to justify the present classification.

3. Substitution deposits, or complete metasomatic replacements.— Through the recent labors of Dr. S. F. Emmons and others, the substitution deposits have been proved to be of great importance, and

[1] Trans. N. Y. Acad. Sci., XIII, pp, 76–98.

many deposits formerly classed as veins are now known to be complete metasomatic replacements. Metasomatic impregnations may be regarded as marking, in general, the halfway point in the development of substitution deposits, although in calcareous rocks the impregnation stage cannot be regarded as essential, the contact between the ore body and the limestone being often sharply defined. Like impregnations, the substitution deposits may or may not occur in the walls of veins or along igneous contacts. Substitution deposits may be divided in the same way as impregnations; but, since they present comparatively little commingling of rock and ore, it is sufficient for our purpose to recognize two sub-types, as follows:

(*a*) *Substitution deposits in calcareous rocks.* The important examples are too numerous for detailed citation, but include the following: the copper deposits in part of the Morenci, Bisbee, and Globe Districts of Arizona, and of the Santa Rita District, New Mexico; and the lead-silver ores of the Leadville, Ten Mile, Monarch, Eagle River, Aspen, and Rico Districts, Colorado; of Galena and Carbonate, South Dakota; of Bingham, and Big and Little Cottonwood Canons, the Crismon-Mammoth vein, and the Horn Silver Mine, Utah; and of the Eureka and White Pine Districts, Nevada.

(*b*) *Substitution deposits in siliceous rocks.* Owing to the greater insolubility of the rocks, the well-identified examples under this type are less extensive, but include the following: the hematite of the Penokee-Gogebic District and the Mesabi Range and, possibly, of Iron Mountain, Missouri; the copper ores of Butte, Montana (extensive replacements of granite along small fissure veins); the veins of native copper on Keweenaw Point; and many so-called gold and silver veins, including the Comstock Lode.

II. Aqueous deposits of superficial origin (sedimentary rocks, etc.). — The history of the superficial aqueous deposits is so much less obscure than that of the subterranean deposits that comparatively brief statements will suffice. Following the order of the lithological classification, we have:

1. Mechanical deposits (fragmental rocks).—These have been deposited from suspension and include:

(*a*) *Normal fragmental rocks,* including the conglomerate, arenaceous, and argillaceous groups, consolidated and unconsolidated.

(*b*) *Placer deposits,* fluvial and marine, ancient and modern. The

sorting action of water has effected the concentration in the rock, at the time of its deposition, of one or more useful minerals, such as gold, platinum, iridosmine, cassiterite, and magnetite, and corundum, topaz, diamond, and other gems. This type may be compared with the original disseminations in igneous rocks, a single constituent and not the entire rock being useful. It is quite unnecessary to cite the numerous gold placer districts of this country. Marine placers occur at Port Orford, Oregon, and Yakutat Bay, Alaska. The gold placers of the Black Hills are in part quaternary and recent, and in part the basement beds of the Potsdam sandstone.

2. Chemical deposits (chemically-formed rocks, etc.).—These have been deposited from solution by:

(*a*) *Oxidation.* The examples include bog limonite, with pond and lake ore; Clinton hematite, oölitic ore, due to deposition of iron oxide in concentric coats about minute grains of quartz, and fossil ore, where the iron oxide is deposited in or replaces water-worn fragments of calcareous organisms; beds of limonite and red hematite in various formations from the Cambrian to the Tertiary; the specular hematite of the Marquette and Menominee Districts (probably); the Vermilion Lake hematite, believed by Prof. N. H. Winchell to be a marine chemical precipitate; the great bed of specular hematite on Pilot Knob, Missouri, (probably); bauxite, and many manganese deposits.

(*b*) *Reduction.* The chief agent is organic matter, and under its influence the soluble sulphates yield native sulphur and various metallic sulphides. Sulphide of iron is extensively deposited in this way in argillaceous sediments; and it may be that some of the great beds and lenses of pyrite have had this origin.

(*c*) *Evaporation.* The chief examples are siderite (black-band, etc.), calcareous and siliceous tufas, gypsum, rock salt, etc. The tufas would be of special interest in a more detailed study as marking the overflow portions of subterranean solutions which formed veins and impregnations on their way to the surface.

3. Organic deposits (organically-formed rocks, etc.).—These have been formed by the accumulation of:

(*a*) *Hydrocarbons*, giving rise to coals, bitumens, etc.
(*b*) *Siliceous organisms*, giving rise to tripolite, etc.
(*c*) *Calcareous organisms*, giving rise to limestones.
(*d*) *Phosphatic materials*, giving rise to guano and phosphate rock.

4. Metamorphic deposits. — Either of the above groups (1, 2, 3), under the combined influence of water, heat, pressure, and chemical change, may become metamorphic (crystalline), affording thus:

(*a*) *Normal metamorphic rocks*, where the rock as a whole may be useful (some of the crystalline iron ores belong here), and

(*b*) *Original disseminations in metamorphic rocks*, where crystallization has developed in the rock minerals (usually accessory, such as garnet and pyrite), which may be of economic interest.

5. Residuary deposits. — These are due to superficial chemical changes (oxidation, hydration, etc.) and commonly to differential chemical erosion. Two principal types may be recognized, as follows:

(*a*) *Oxidized and partially oxidized, and residuary metalliferous deposits* (including gossan). The chief examples are the residuary ores of iron and manganese, including the limonite deposits of the Great Valley, the great deposit of magnetite at Cornwall, Pennsylvania, being, perhaps, a metamorphic example of one of these. The Clinton ore (hematite) is due in part to the differential erosion of ferriferous limestone. The beds of conglomerate iron ore mantling Iron Mountain and Pilot Knob, Missouri, are virtually ancient residuary deposits.

(*b*) *Residuary earthy and siliceous deposits*, including a large proportion of the ordinary superficial detritus or soil and some phosphate deposits, kaolin being the most important single example.

In conclusion, it may be noted that it is not a valid argument against this or any classification that our ideal types are far simpler, in most cases, than the actual deposits; for a classification, to have any value, must isolate causes and exhibit phenomena in their elements. Thus, for example, actual veins are usually combined with impregnations and replacements, and on the surface mechanical, chemical, and organic deposition go hand in hand; and we cannot ordinarily say of a deposit that it belongs to this or that type, but to this or that combination of types.

OUTLINE OF THE CLASSIFICATION.

A. Deposits of igneous origin (igneous rocks).

I. Igneous deposits of subterranean origin (plutonic rocks).

(*a*) Normal plutonic rocks.

(*b*) Excessively basic plutonic rocks.

(*c*) Original disseminations in plutonic rocks.

(*d*) Sublimates in fissures.

II. Igneous deposits of superficial origin (volcanic rocks).

(*a*) Normal volcanic rocks or lavas.
(*b*) Excessively basic volcanic rocks.
(*c*) Original disseminations in volcanic rocks.
(*d*) Sublimates on lava.

B. Deposits of aqueo-igneous origin.

C. Deposits of aqueous origin.

I. Aqueous deposits of subterranean origin (vein rocks, etc.).

1. Veins, or deposits in preëxisting cavities.

(*a*) True fissure veins.
(*b*) Crushed-zone or shear veins.
(*c*) Joint or gash veins.
(*d*) Interbedded veins.
(*e*) Neck veins.
(*f*) Crenitic veins.
(*g*) Cavern veins.
(*h*) Brecciated cavern veins.

2. Impregnations.

(*a*) Concretionary deposits, not metasomatic.
(*b*) Concretionary deposits, metasomatic.
(*c*) Amygdaloidal deposits.
(*d*) Interstitial deposits.
(*e*) Metasomatic deposits in calcareous rocks.
(*f*) Metasomatic deposits in fragmental rocks.
(*g*) Metasomatic deposits in igneous rocks.
(*h*) Metasomatic deposits in metamorphic rocks.

3. Substitution deposits.

(*a*) Substitution deposits in calcareous rocks.
(*b*) Substitution deposits in siliceous rocks.

II. Aqueous deposits of superficial origin sedimentary rocks, etc.).

1. Mechanical deposits (fragmental rocks).

(*a*) Normal fragmental rocks.
(*b*) Placer deposits.

2. Chemical deposits (chemically-formed rocks, etc.).
   (*a*) Oxidation deposits.
   (*b*) Reduction deposits.
   (*c*) Evaporation deposits.

3. Organic deposits (organically-formed rocks, etc.).
   (*a*) Hydrocarbons.
   (*b*) Siliceous rocks.
   (*c*) Calcareous rocks.
   (*d*) Phosphatic rocks.

4. Metamorphic deposits.
   (*a*) Normal metamorphic rocks.
   (*b*) Original disseminations in metamorphic rocks.

5. Residuary deposits.
   (*a*) Residuary metalliferous deposits.
   (*b*) Residuary earthy and siliceous deposits.

MOMENT OF INERTIA OF SOLID OF REVOLUTION.

By ALBERT F. HALL, S.B.

Received March 23, 1894.

Mr. Amsler has proposed a method for finding the moment of inertia of solids of revolution, a description of which has been kindly sent to the writer by Professor Coleman Sellers.[1] The following modified treatment and its application to a fly-wheel will, perhaps, be of interest to many of the *Quarterly's* readers:

From the unshaded area A, Figure 1, construct the shaded area by drawing any line, as B, parallel to the axis of rotation and radial lines similar to $\overline{oo}$. Conceive an infinitely thin wedge A_2 cut from the solid, such that $x_1 dy$ shall be equal to dt, or $y d\theta$, then, calling V the volume of the solid, $V = \iint x y dy d\theta$. But $x = \frac{cx_1}{y}$ $\therefore$ $V = \iint c x_1 dy d\theta$. If $A_1 =$ section $A +$ the shaded area, then $V = \iint c dA_1 d\theta$ and

$$V = cA_1 \int_0^{2\pi} d\theta = 2\pi c A_1.$$

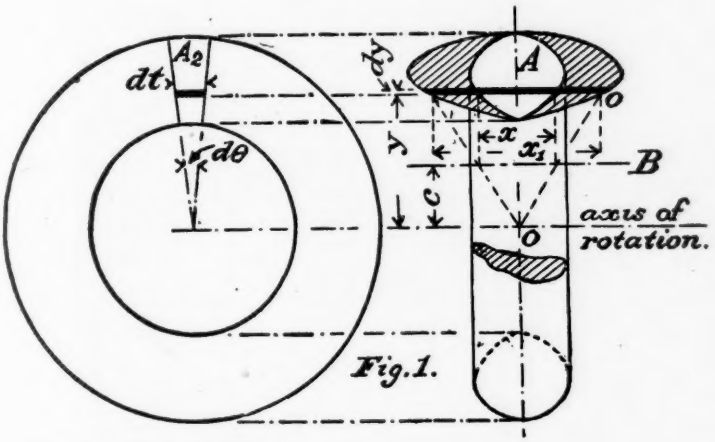

Fig. 1.

[1] See the Stevens Indicator, October, 1893, Vol. X, No. 4, page 263.

Let I_p = the moment of inertia of the solid, then

$$I_p = \iint y^2 x dy dt = \iint y^2 \frac{cx_1}{y} dy \qquad y d\theta = \iint c d\theta y^2 x_1 dy \text{ or}$$

$$I_p = c \int_0^{2\pi} d\theta \int y^2 x_1 dy = 2\pi c I$$

where I = moment of inertia of A_1 about the axis of rotation. The radius of gyration $= \rho = \sqrt{\frac{I_p}{V}} = \sqrt{\frac{I}{A_1}}$.

APPLICATION TO THE RIM OF A FLY-WHEEL.

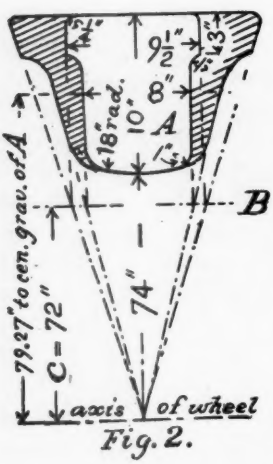

Fig. 2.

c = 72 inches. A = 82.98 square inches. A_1 = 91.42 square inches. I = 576707.02. $V = 2 \times \pi \times 72 \times 91.42 = 41357.42$ cubic inches.

The center of gravity of A from the axis = 79.27 ∴ the volume of rim is also:

$V = 2 \times \pi \times 79.27 \times 82.98 = 41329.69$ cubic inches, or 0.9993 of the first value, which shows the accuracy of the drawing.

$$\rho = \sqrt{\frac{576707.02}{91.42}} = 79.42''.$$

Had the radius to the center of gravity been used, the error would have been only

$$\frac{(79.42 - 79.27) \times 100}{79.42} = \frac{19}{100} \text{ of one per cent.,}$$

which shows that in such a case the radius to the center of gravity of the section A is sufficiently accurate.

The above calculations were made with the aid of an Amsler "Mechanical Integrator" which gives areas, statical moments, and moments of inertia of plane surfaces.

THE ELECTRICAL PURIFICATION OF WATER.

By THOMAS M. DROWN, M.D.

Received April 9, 1894.

In this electrical age when a new application of electricity to every-day needs is a matter of daily experience, it does not surprise any one to hear of the practical use of electricity as a purifying and disinfecting agent, particularly as we are accustomed to think of it as a force which purifies as well as destroys. The electrical purification of water and sewage appeals to most persons, therefore, as a process likely to be both potent and effective. There is, moreover, to some minds a peculiar satisfaction in the contemplation of a subtle force which acts in a mysterious way, and to such minds an explanation is often an unwelcome disillusion. Inasmuch as considerable prominence has been given in the last decade to methods of electrical purification of water and sewage, it may not be uninteresting to state briefly just how this purification is effected and the principles on which it rests.

We may distinguish two classes of so-called electrical purification: (1) Those which electrolyze water, liberating oxygen at the positive pole; and (2) those which electrolyze a solution of common salt and liberate chlorine in the same way.

The Webster process for the purification of sewage, of which a good deal was once heard, belonged mainly to the first class, although, by reason of the chlorides contained in the sewage, it fell also, in part, into the second class. The oxygen liberated at the positive pole, while in the nascent state, was supposed to oxidize some organic matter; but as this pole was composed of iron plates the oxygen was mainly consumed in oxidizing this iron, and the oxide of iron thus formed acted as a precipitating agent on the sludge in the sewage. The process was thus mainly one of chemical precipitation of sewage by means of oxide of iron, which was formed by a current of electricity

passing through the sewage. Much was hoped from this process, but it never passed, as far as I am aware, beyond the experimental stage.

The possibility of oxidizing organic matter on a large scale, by means of nascent oxygen liberated from water by the electric current, will probably never be more than a dream. Attractive as the process seems, the necessary conditions for accomplishing it could probably never be realized on a city's water supply or on its sewage. One word in this connection about the nascent state of an element, of which we hear so much nowadays. It is a well-known chemical fact that elements just liberated from combinations are much more active than in their ordinary condition. Nascent hydrogen, for instance, is a powerful reducing agent; nascent oxygen a powerful oxidizing agent — properties which are lost when these elements have assumed their molecular condition.

In some of the recent literature which I have read on the electrical purification of water, I have come across the idea that a nascent substance is one that is fresh in contradistinction to one that is stale; as if, for instance, oxygen liberated from water a minute ago would be more active than if it had been formed one hour. This is very wide of the mark; it is only at the very instant of formation that an element has enhanced powers due to its nascent or new-born condition.

The more recent systems of purification of water and sewage by electricity belong in the second class, that is, the decomposition, by electrolysis, of a solution of common salt. When a solution of salt (chloride of sodium) is decomposed by electricity, we have sodium liberated at one pole and chlorine at the other. The sodium is immediately oxidized and combines with the water present, and a solution of caustic soda results. By suitable mechanical contrivances the chlorine gas may be conducted away from the other pole as fast as liberated and collected as such. This method of making caustic soda, it may be said incidentally, is yet more or less in its experimental stage; but it seems not unlikely that the electrolytic production of caustic soda from common salt may become one of the world's great industries.

But if instead of separating the caustic soda and chlorine from each other in this process they are allowed to recombine, we have a complicated series of reactions, resulting in the formation of various products dependent on the concentration of the liquid and its temperature. The principal product under ordinary conditions is sodium

hypochlorite, variously named chlorinated soda, chloride of soda, and, in pharmacy, Labarraque's solution. A corresponding and entirely analogous compound is the so-called chloride of lime or bleaching powder, in which lime takes the place of soda.

This, then, is the substance, sodium hypochlorite, with which we have to deal in the method of electrical purification which depends on the electrolysis of a solution of salt or sea water. When the current of electricity has, in the manner above described, formed a sufficiently concentrated solution of sodium hypochlorite, this solution is mixed with the sewage or water to be purified.

I would remark, first, that there is nothing new in the application of electricity to produce the hypochlorites, except so far as the introduction of the modern dynamo enables us to generate electricity at a much less cost than formerly, and consequently to use it economically in industrial chemical operations. Second, there is nothing new in the use of sodium hypochlorite as a disinfectant, deodorizer, and germicide. In the very valuable report on disinfectants published by the American Public Health Association in 1888, the hypochlorites were shown, experimentally, to be among the most effective of all disinfectants in their action; 1 per cent. of a solution of sodium hypochlorite, containing 6 per cent. of available chlorine, destroyed the "bacillus anthracis" in two hours; 2 per cent. of this solution was effective in thirty minutes.

Of the corresponding lime salt, or bleaching powder, the committee reported that a solution of this substance containing 25 per cent. of available chlorine was effective in a 1 per cent. solution in one or two minutes, and that a solution of one fourth of this strength would kill "bacillus anthracis" and "bacillus subtilis" in two hours. The two hypochlorites of sodium and calcium were thus shown to be equally efficacious, the activity depending on the amount of hypochlorous acid present, or, in other words, of available chlorine.

The so-called electrical purification of water by treating it with an electrolyzed solution of salt is thus seen to be simply a process of disinfection by sodium hypochlorite; electricity, as such, has nothing to do with it. There is nothing peculiar in the sodium hypochlorite produced by electrolysis; it has no different properties from that made by the ordinary process of passing chlorine into a solution of caustic soda. That other compounds are formed in small amounts by the action of chlorine on caustic soda is true, but it has not been

shown, nor is it probable that any one of them has as potent germicidal and oxidizing power as the hypochlorite.

Ozone is generally supposed to cover a multitude of sins of pollution and quietly to destroy them; but we do not know much, if anything, about its germicidal power, and there is certainly no good reason for attributing any of the disinfecting action of an electrolyzed salt solution to ozone, even did we certainly know it to be present.

It is unfortunate, I think, that the advocates of this system of purification of water and sewage are not content to attribute the purifying action of the electrolyzed solution of salt solely to the hypochlorite formed. There is nothing gained scientifically by calling it "electrozone" or an "electro-saline solution," for there is nothing mysterious about its action, as these terms would lead one to suppose. Nor is it proper to speak of this system of purification in any sense as an electrical one. If one were to purchase two bottles of sodium hypochlorite of identically the same composition, one prepared by a chemical process and the other by the electrolysis of a salt solution, he would not expect to find them called by different names. To call the latter an "electrical disinfectant" would be simply fantastic.

Finally, is it desirable in any case to treat a city's water supply with a powerful disinfectant like the hypochlorites? When the question is put in this bald form I cannot think it will receive the approval of engineers and sanitarians. Leaving out of consideration the difficulties and cost of disinfecting effectively and uniformly the water supply of a large city, the idea itself of chemical disinfection is repellent. Every city should jealously guard its water supply. It is a sin against decency and good morals to permit the pollution of drinking water by sewage and house drainage. It is a still greater wrong, not to say a foolish blunder, to permit the open pollution of its drinking water streams and then systematically to disinfect them.

In cases where a water supply has got into such a hopelessly bad condition that nothing will render it safe but disinfection by chloride of soda or chloride of lime, it is high time, I think, to abandon the supply, and in this opinion I feel sure most waterworks engineers will coincide.

ON THE DETERMINATION OF NITRATES IN POTABLE WATER BY THE PHENOLSULPHONIC ACID PROCESS.

By AUGUSTUS H. GILL, Ph.D.

Received February 28, 1894.

Recent criticisms of the phenolsulphonic acid process for the determination of nitrates in water show that the conditions for its successful working have not been fully understood, and that all the sources of error which may arise in the treatment of natural waters and sewage effluents by this process have not been known.[1]

The process is so very simple and its execution requires so little time that it seemed worth while to give it further systematic study in order, if possible, to determine all the conditions of its successful use.

The investigation was conducted with reference to the following points :

I. Acids.
- *a.* Various acids.
- *b.* Method of treatment.
- *c.* Quantity of acid used.

II. Evaporation.
- *d.* Effect of sodium carbonate.
- *e.* Temperature at which it is carried on.
- *f.* Quantity evaporated.
- *g.* Effect of chlorine.

III. Comparison with Standards.

The preparation of the phenolsulphonic acid is a matter of first importance, and for which, strange to say, no one has ever given defi-

[1] This process originated with Sprengel, Poggendorff's Annalen, **121**, 188, and apparently fell into disuse until again brought to notice by Grandval and Lajoux, Comptes rendus, **101**, 62. Since then articles upon it have appeared by Fox, Technology Quarterly, 1, 1; Johnson, Chemical News, **61**, 15; Lindo, Chemical News, **58**, 1, 15, 28; Smith, Analyst, **10**, 197; Bartram, Journal of the Franklin Institute, March 17, 1891; and Hazen and Clark, Journal of Analytical and Applied Chemistry, **5**, 1.

nite directions. Kekulé[1] found when phenol and sulphuric acid were mixed, according to the temperature, varying amounts of ortho and para phenol monosulphonic acids were formed. As these could not fail to influence the action upon the dry-water residue, an acid of perfectly definite composition — the pure disulphonic acid $C_6H_3OH(SO_3H)_2$, probably $OH : SO_3H : SO_3H = 1 : 2 : 4$, which with nitric acid gives *picric acid even in the cold*[2] — has been mostly used in these experiments.

This is prepared as follows: Three grams of phenol of good quality and thirty-seven grams of pure sulphuric acid sp. gr. 1.84 (Kahlbaum's synthetic phenol and Baker and Adamson's "Strictly Pure" sulphuric acid were usually employed) are mixed in a flask and heated for six hours *in, not upon,* a water bath to 100°.

To determine the number of sulphonic groups, a portion of this mixture was neutralized with barium carbonate, lixiviated with water, filtered, the filtrate evaporated and the barium salt recrystallized, giving handsome orthorhombic prisms. A determination of barium in this gave 35.16 per cent., the theory requiring 35.22 per cent. A determination of water of crystallization gave 15.66 per cent., theory, 15.62 per cent. H_2O. The acid as thus prepared may crystallize out upon standing, it being rather insoluble in the strong sulphuric acid, in which it forms supersaturated solutions. It may be brought into solution by reheating a short time, or by dilution with a small quantity of water; the undiluted acid has always been used.

The experiments were performed as follows: Two solutions were employed, one containing, in 1 cc., 0.1000 part of nitrogen per 100,000 as potassium nitrate; the other, in addition to this, seven parts chlorine as sodium chloride per 100,000. Of these, portions of 1 cc. each were measured out and diluted to 5 and 10 cc. with distilled water and evaporated in porcelain dishes.[3]

The $2\frac{1}{2}$-inch evaporator containing the water residue was moistened with ten drops — 0.7 cc. — of the phenolsulphonic acid, and by rubbing with a short glass rod every part of the residue covered with it; 7 cc. of water are now added — measured in later experiments by a Vanier[4] overflow pipette — the solution stirred, and 3 cc. am-

[1] Zeitschrift für Chemie, 10, 199.

[2] Kekulé, Lehrbuch, III, 236.

[3] A convenient way of marking these dishes is to remove a small patch of the glaze upon the outside of the dish by glass etching ink, leaving a rough surface for the lead pencil.

[4] Journal of Analytical and Applied Chemistry, 2, 145.

monium hydrate, measured in like manner, added, the solution again stirred to insure uniformity, and the rods removed. In many cases the colors could be compared directly in the dishes, but in case of doubt the comparison took place in tubes about $1\frac{5}{8}$ inches deep and $\frac{5}{8}$ inch in diameter.

Each determination is the average of at least two closely agreeing determinations.

All results are stated in parts per 100,000.

I. ACIDS.

(*a*) VARIOUS ACIDS.

Equal parts of phenol and sulphuric acids.	The colors obtained were brown and an accurate matching was impossible.
Unknown mixture of ortho and para sulphonic acids from 5 per cent. solution of phenol.	The colors obtained were fairly good, but in some cases were reddish tinted.
Pure ortho phenol monosulphonic acid.[1]	This gave a precipitate with the ammonia, and the colors were all bluish-green tinted.
Pure disulphonic acid, $7\frac{1}{2}$ per cent. solution.	The colors obtained were a pure yellow and did not change upon standing. This, therefore, gives the best results.

(*b*) METHOD OF TREATMENT.

At 100°. — Sprengel[2] states that the residue should be nearly at 100° when treated. Experiments performed by treating the residues upon the steam bath with the cold acid and also with the acid at 100° gave no better results than those obtained in the ordinary way.

At 0°. — Treatment of the chilled residues upon ice with ice-cold acid gave decidedly lower results than those obtained in the usual manner, the nitration probably not going as far.

Addition of substances. — The addition of phenol or phenolsulphonic acid to the water before evaporation is of no advantage whatever.

(*c*) QUANTITY OF ACID USED.

If chlorine be absent, or in small quantity, the amount of acid used makes very little difference. Enough should be used to cover the residue readily, usually ten drops = 0.7 cc. is sufficient. For example,

[1] Prepared by the cold evaporation in vacuo of the officinal solution of Merck's "Aseptol" and subsequent solution in sulphuric acid.

[2] Poggendorff's Annalen, 121, 188.

with equal quantities of the same nitrate solution which should have given a reading of 0.1000, the following results were obtained:

TABLE I.

Showing the effect of the quantity of acid used.

Without Chlorine.		With Chlorine, seven parts.	
10 drops acid.	6 drops.	10 drops acid.	6 drops.
0.0925	0.0900	0.0750	0.0700

It is evident, then, that the use of too little acid causes the loss of nitric acid.

II. EVAPORATION.

It is well known that certain salts in solution undergo decomposition when boiled. Fittig[1] found this to be true of ammonium chloride; Debbits,[2] of several acetates with loss of acetic acid, and with the nitrate, sulphate, acetate, and oxalate of ammonium with loss of the respective acids. Leeds[3] and Fox[4] have shown that nitrates are volatile at 100° and even lower temperatures.

In order to ascertain what the influence of the evaporation really was, the following experiment was tried:

An intimate mixture of dry, finely powdered potassium sulphate and nitrate was made by grinding them together in an agate mortar for several hours. Sixteen portions of 100 milligrams each were accurately weighed out, each containing about 0.072 milligram of potassium nitrate. Twelve portions were dissolved each in 10 cc. of water; four of these evaporated at 100°, four at 65°, and the remaining four at 20° over sulphuric acid.

TABLE II.

Showing loss of nitrate by evaporation at various temperatures.

	Dry.	20°.	65°.	100°.
I	0.1000	0.0890	0.0900	.....
II	0.1050	0.1000	0.1080	0.1160

The readings varied among themselves by 0.0200 and hence were averaged.

[1] Annalen der Chemie und Pharmacie, 128, 189.
[2] Berichte der deutschen chemischen Gesellschaft, 5, 820.
[3] American Journal of Science (3), 7, 197.
[4] Technology Quarterly, 1, 1.

To obviate this variation, sixteen portions of 1 cc. each of a nitrate solution were measured out, 9 cc. of water added, and all allowed to evaporate over sulphuric acid at a temperature of 20°. Ten cc. of water were added to each one of twelve of these, and four evaporated at 20°, four at 65°, and four at 100°; this gave a series in which exactly the same amount of nitrate in every case was spread uniformly over the dishes and had been subjected to these various temperatures.

TABLE III.

Showing loss of nitrate by evaporation at various temperatures.

Dry.	20°.	65°.	100°.
0.1000	0.0990	0.0965	0.0990

These results indicate that there is a loss of about 1 per cent. when the water is allowed to evaporate at ordinary temperatures over sulphuric acid, or in a steam bath where it evaporates rapidly and is *immediately* removed; at 65°, where the evaporation is slower and the time of exposure to heat consequently lengthened, the loss is greater, in this case about $3\frac{1}{2}$ per cent.

(*d*) EFFECT OF SODIUM CARBONATE.

With a view of fixing the nitric acid, and thus diminishing the loss by evaporation, it has been suggested that carbonate of sodium be added to the water before evaporation; as carbon dioxide is given off upon treatment with acid, it is possible that this carries off with it a slight quantity of nitric acid. Ten portions each of nitrate solution, the reading of which should have been 0.1000, were evaporated; the average reading was 0.0970, with the addition of soda, 0.0973. Ten portions each of the same solution, containing in addition seven parts chlorine per 100,000, when similarly treated gave 0.0821, with the addition of soda, 0.0812.

The avidity of acetic acid being much less than that of nitric acid, added to the fact that it was non-volatile at the temperatures employed, led to the suggestion that some of its salts be employed as a substitute for the sodium carbonate. Sodium acetate when added to the water gave rather lower results than those obtained when it was not used.

(*e*) TEMPERATURE AT WHICH EVAPORATION IS CARRIED ON.

The accompanying table shows clearly the effect of temperature upon the determination.

The solutions should have all read 0.1000 part nitrogen as potassium nitrate per 100,000, they were all treated with carbonate of sodium, and each figure represents the mean of two closely agreeing determinations.

TABLE IV.

Effect of temperature. Pure nitre solution.

Temp.	Quantity evaporated. 1 cc.	5 cc.	10 cc.
100°	0.0925	0.0920	0.0920
65°	0.0890	0.0890	0.0880
20°	0.1050	0.0980	0.1000

Nitre solution with 7.0 parts chlorine.

Temp.	Quantity evaporated. 1 cc.	5 cc.	10 cc.
100°	0.0680	0.0700	0.0600
65°	0.0650	0.0650	0.0680
20°	0.0935	0.0920	0.0700

It is evident that there is a decided loss of nitrate when evaporation takes place at 65° (the temperature which water assumes in a porcelain dish when upon the top of a water bath) over that lost at 100°, and here even over that lost at 20°. With chlorine this is even more perceptible; the reason for the increased loss at 65° is probably, as already stated, that the time of exposure at this temperature is longer.

It is important, however, that the dishes be removed as soon as dry, as the subsequent exposure causes loss of nitrate.

TABLE V.

Effect of heat upon the dry residue.

Water contained 0.1000 part N as N_2O_5, 7.0 part Cl.

	Quantity evaporated. 1 cc.	5 cc.	10 cc.
Removed at once	0.0750	0.0710	0.0740
Exposed half an hour at 65°	0.0700	0.0625	0.0690

(*f*) QUANTITY OF SOLUTION EVAPORATED.

The quantity of solution evaporated seems to exercise but slight influence upon the results, although the smaller it is the less the loss; this is evident from all three of the preceding tables.

(*g*) EFFECT OF CHLORINE.

The presence of large quantities of chlorides in the water does unquestionably lower the results. If the process be conducted in the usual way, by the evaporation of 10 cc. at 100° it shows, in Table IV, a loss of from 30 to 40 per cent. of nitrogen as nitrate. If a smaller quantity, 5 cc., or even 1 cc., be used, and the evaporation be carried on at 20° over sulphuric acid, this loss is reduced to 6 or 7 per cent., and of this probably one half is due to unavoidable errors in matching the colors.

If the chlorine amounts to but 2.0 parts per 100,000, which is perhaps high in waters of doubtful character, it exercises practically no influence.

TABLE VI.

Effect of 2 0 parts of chlorine (as NaCl) per 100,000. Readings should be 0.1000.

	1 cc.	10 cc.
100°	0.0900	0.0900 (average of five determinations.)
65°	0.0900	0.1000
20°	0.0975	0.1050

III. COMPARISON WITH STANDARDS.

The yellow color of the picrate solution when as high as 0.1000 is extremely hard to match accurately; the tints must be read off at once without any delay, as the difficulty increases with the time spent in comparison. It is well after reading perhaps a dozen to rest the eyes by looking intently at a piece of blue paper.

As a result of a long series of experiments upon three different people — all experts in the comparison — it was found that the error of reading colors up to 0.0500 part N as N_2O_5 was 0.0020 or 0.0030; up to 0.1000 part N as N_2O_5 was 0.0050.

No advantage was gained by the use of colored glasses, or, when the colorimeters were used, of colored papers underneath them.

The process does not, as stated by Grandval and Lajoux,[1] and also in Graham-Otto,[2] estimate the nitrogen present as nitrites; this is clearly impossible, as the action of nitrous acid upon phenolsulphonic acid results in the formation of nitrosophenol, $C_6H_4\overset{NO}{OH}$, which is colorless in dilute solutions. This view was supported by an experiment

[1] Comptes rendus, **101**, 62.

[2] Lehrbuch der anorganischen Chemie, **2**, Part 1, 200.

with pure sodium nitrite prepared from pure silver nitrite, in which no color whatever was obtained upon treatment with the phenolsulphonic acid.

The results of this paper may be summarized as follows:

The most satisfactory manner of execution is — in the case of a water high in nitrates — to use that quantity which will give a reading of about 0.0700 when 1 or 2 cc. are employed; in the case of ground water 10 cc. of a portion which has been decolorized by the use of alumina in the cold is evaporated upon the water bath, the dish being placed in the steam and removed *as soon as dry*, or, better, when a drop is still remaining. In case the chlorine be high, which often accompanies high nitrates, this evaporation had best take place in vacuo over sulphuric acid, and the chlorine, if it exceeds 7.0 parts per 100,000, removed by silver sulphate which has been proved to be free from nitrate.[1]

In case 1 or 2 cc. of the water is used, the 0.7 cc. of acid used is sufficient to cover the residue completely.

The error of reading up to 0.0500 is 0.0020 or 0.0030, 4 to 6 per cent.; up to 0.1000 is 0.0040 or 0.0050, 4 to 5 per cent.; but the process as here described is more trustworthy, delicate, and accurate than any process yet published.

For easy comparison 0.720 gram KNO_3 can be dissolved in one liter of water, 10 cc. of this allowed to evaporate in vacuo, treated with acid, made up to a liter, and portions as wanted, made alkaline with ammonia; of this solution 10 cc. = 0.1000 part nitrogen as potassium nitrate per 100,000.

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[1] Silver sulphate marked "C. P." from a well-known German source contained enough nitrate to vitiate all results.

THE EFFECT OF HEAT UPON THE DIGESTIBILITY OF GLUTEN.

By ELLEN H. RICHARDS, A.M., S.B., and ELIZABETH MASON, A.B.

Received April 20, 1894.

The following short series of experiments was suggested by the statement of A. Stutzer, in an article on the digestibility of albuminoids,[1] that cooking lessened the digestibility of vegetable albuminoids. A "purified gluten," prepared by the New York Health Food Company and containing 9.05 per cent. of nitrogen, was the substance selected for the experiments, which were carried on in the following way:

An artificial gastric juice was first prepared with five grams of pepsin (marked A) and two tenths of 1 per cent. of hydrochloric acid to a liter of water. This solution was used in the proportion of one hundred cubic centimeters to every gram of the material to be digested.

Flasks containing the mixture were tightly corked to prevent loss by evaporation and allowed to remain for four hours in a water bath kept at blood heat. They were frequently shaken to insure as complete action as possible, and at the end of that time the solution was filtered and ten cubic centimeters of the filtrate subjected to the Kjeldahl process for the determination of nitrogen.

Fresh samples of gluten were next treated in a similar way with water containing two tenths of 1 per cent. of hydrochloric acid, in order to compare the action of acidulated water with that of acid solution of pepsin. The latter was found to be the more effective, as it dissolved nearly 7 per cent. of nitrogen, while the former dissolved but 5.

Further experiments also showed that fifteen minutes' digestion gave as satisfactory results with this pepsin solution as four hours'.

[1] In abstract in Vierteljahresschrift der Chemie der Nahrungs-u. Genussmittel, 1891, p. 87.

A second sample of pepsin (marked B) was soluble in acidulated water, and proved to be more active than the first. A solution containing $\frac{1}{2}$ gram per liter dissolved 8 per cent. of nitrogen in the same time that 5 grams per liter of sample A dissolved 7 per cent.

Wafers were then made of gluten and cream, baked till brown, ground to a fine meal, and portions of the meal were subjected to artificial digestion for fifteen and thirty minutes, and four hours, respectively. The longest treatment failed to dissolve as large a proportion of nitrogen as had been obtained from the raw material in fifteen minutes.

Lastly a gruel was made by taking one gram of gluten, mixing it with five cubic centimeters of cold water, adding fifty cubic centimeters of boiling water, and allowing the whole to simmer for half an hour. Acid solution of pepsin was then added and the gruel allowed to digest in the same flask for fifteen minutes.

Similar experiments were then made in which the time of digestion was prolonged to thirty minutes and four hours, respectively. From these it was found that, although in four hours nearly all the available nitrogen was dissolved, in fifteen minutes only five eighths of that amount was made available.

The accompanying tables give the results obtained, all tending to confirm Stutzer's statement as to the effect of heat on the digestibility of the vegetable albuminoids.

PURIFIED GLUTEN. RAW MATERIAL.

Total nitrogen	9.05 per cent.
Moisture	9.42 per cent.

EFFECT OF TREATMENT WITH HYDROCHLORIC ACID AND PEPSIN.

Solution used.	Time of treatment.	Per cent. of nitrogen dissolved.
Acidulated pepsin "A," 5 grams to the liter	4 hours.	6.91
Acidulated pepsin "A," 5 grams to the liter	15 minutes.	6.95
Acidulated pepsin "B," $\frac{1}{2}$ gram to the liter	15 minutes.	8.00
Dilute hydrochloric acid	4 hours.	4.64

GLUTEN COOKED.

Wafers.

Total nitrogen, 7.28 per cent.

Solution used.	Time of treatment.	Per cent. of nitrogen dissolved.
Acidulated pepsin "B," ½ gram to the liter	15 minutes.	2.98
Acidulated pepsin "B," ½ gram to the liter	30 minutes.	4.23
Acidulated pepsin "B," ½ gram to the liter	4 hours.	5.63

Gruel.

Solution used.	Time of treatment.	Per cent. of nitrogen dissolved.
Acidulated pepsin "B," ½ gram to the liter	15 minutes.	5.05
Acidulated pepsin "B," ½ gram to the liter	30 minutes.	6.22
Acidulated pepsin "B," ½ gram to the liter	4 hours.	8.06

A PROPOSED FORMULA FOR WHITE PINE POSTS.

By JAMES H. STANWOOD, S.B.

Received May 24, 1894.

An article by the present writer, entitled "A Proposed New Formula for Yellow Pine Posts," appeared in the *Technology Quarterly* for April–July, 1892, Volume V, page 104. It was a straight-line formula of the form

$$S = 4{,}250 - 43\tfrac{1}{3}\,\frac{l}{d}$$

representing the average of the lowest breaking values of a series of tests made on *full size* sticks at the Watertown Arsenal. The working formula

$$s = 1{,}000 - 10\,\frac{l}{d}$$

was recommended,

s = allowable stress per square inch.
l = length of piece in inches.
d = smaller diameter in inches.

assuming the factor of safety of $4\frac{1}{4}$, approximate.

The object of the present article is to bring to notice a similar formula for *White Pine Posts.* As in the former case, the tests were made at the Watertown Arsenal on *full size* sticks, and each test has been plotted with the breaking load in pounds per square inch for the ordinate, and the ratio of l to d for the abscissa, as shown in the cut. An average line for the lowest breaking loads in each set of tests has been drawn whose equation is

$$S = 3{,}150 - 40\,\frac{l}{d},$$

Using the factor of safety of 4, we may write

$$s = 800 - 10\frac{l}{d}.$$

Of course, any other factor of safety may be used, and if the formula of the style

$$S = \frac{K}{1 + \frac{1}{a}\frac{l^2}{d^2}}$$

is preferred, we may use for breaking loads

$$S = \frac{3{,}200}{1 + \frac{1}{1{,}200}\frac{l^2}{d^2}}$$

which gives very nearly the same results as the simpler form above.

Considerable search has been made for tests on *full size* posts of *oak* and *spruce*, but without success. Judging from the tests on small-size specimens made at Watertown Arsenal for the Tenth Census,[1] and also from the results of tests on large-size beams[2] made by Professor Lanza and noted in his "Applied Mechanics," we may assume, in the absence of other information, that yellow pine and white oak have about the same value, and that white pine and spruce also are nearly equal in strength, as posts.

The following is recommended for the allowable stresses per square inch:

Yellow pine or white oak $s = 1{,}000 - 10\frac{l}{d}$.

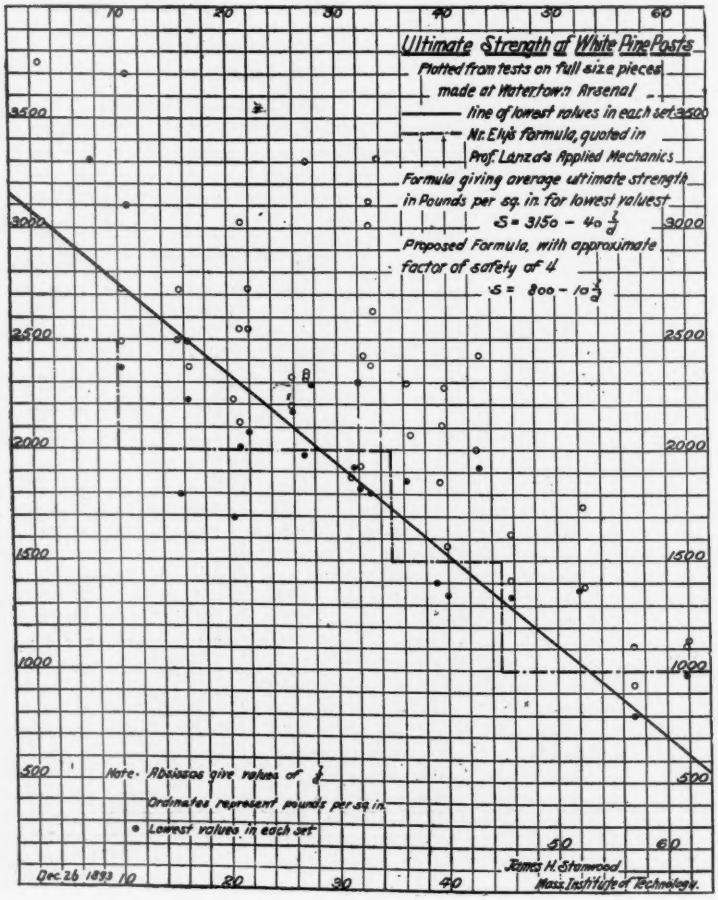
with a factor of safety of $4\frac{1}{4}$

White pine or spruce $s = 800 - 10\frac{l}{d}$

with a factor of safety of 4.

	Yellow pine.	White oak.	White pine.	Spruce.
[1] Average value of tests in pounds per sq. inch,	7,000	7,100	5,000	4,900
[2] Average value of tests in pounds per sq. inch,	7,300	6,100	4,800	4,900

The tables herewith have been computed from the above formulas and may be found useful for reference. Since writing the above, some tests on full size spruce posts have been made on the new Emery Testing Machine, by Professors Lanza and Miller, and the results agree very closely with the above recommended formula.


Ultimate Strength of White Pine Posts
Plotted from tests on full size pieces made at Watertown Arsenal
line of lowest values in each set
Mr. Ely's formula, quoted in Prof. Lanza's Applied Mechanics
Formula giving average ultimate strength in Pounds per sq. in. for lowest values
S = 3150 - 40 l/d
Proposed Formula, with approximate factor of safety of 4
S = 800 - 10 l/d
Note. Abscissas give values of l/d
Ordinates represent pounds per sq. in.
Lowest values in each set
James H. Stanwood
Mass. Institute of Technology.
Dec. 26 1893

Safe Loads, in Pounds, for White Pine Struts.

Computed from the Formula.. 800 − 10 $\frac{l}{d}$, l = length in inches, d = smaller diameter in inches. This formula was obtained by plotting all experiments on full size pieces made at Watertown Arsenal and represents the average of all the lowest breaking weights in each set of tests.

James E. Stanwood,

Mass. Institute of Technology.

Size	6 ft.	8 ft.	10 ft	12 ft.	14 ft.	16 ft.	18 ft.	20 ft.
4×4	9 900	9 000	8 000					
4×6	14 900	13 400	12 000					
4×8	19 800	17 900	16 000					
4×10	24 800	22 400	20 000					
4×12	29 800	26 900	24 000					
6×6	24 500	23 000	21 600	20 200	18 700	17 300		
6×8	32 600	30 700	28 800	26 900	25 100	23 000		
6×10	40 800	38 400	36 000	33 600	31 100	28 800		
6×12	49 000	46 100	43 200	40 300	37 400	34 500		
6×14	57 100	53 800	50 400	47 000	43 700	40 300		
6×16	65 300	61 400	57 600	53 800	49 900	46 100		
8×8	45 400	43 500	41 600	39 700	37 800	35 800	33 900	32 000
8×10	56 800	54 400	52 000	49 600	47 200	44 800	42 400	40 000
8×12	68 200	65 300	62 400	59 500	56 600	53 800	50 900	48 000
8×14	79 500	76 200	72 800	69 400	66 100	62 700	59 400	56 000
8×16	90 800	87 000	83 200	79 400	75 500	71 700	67 800	64 000
8×18	102 200	97 900	93 600	89 300	85 000	80 600	76 300	72 000
10×10	72 800	70 400	68 000	65 600	63 200	60 800	58 400	56 000
10×12	87 400	84 500	81 600	78 700	75 800	73 000	70 100	67 200
10×14	101 900	98 600	95 200	91 800	88 500	85 100	81 800	78 400
10×16	116 500	112 600	108 800	105 000	101 100	97 300	93 400	89 600
10×18	131 000	126 700	122 400	118 100	113 800	109 400	105 100	100 800
12×12	106 600	103 700	100 800	97 900	95 000	92 200	89 300	86 400
12×14	124 300	121 000	117 600	114 200	110 900	107 500	104 200	100 800
12×16	142 100	138 200	134 400	130 600	126 700	122 900	119 000	115 200
12×18	159 800	155 500	151 200	146 900	142 600	138 200	133 800	129 600
14×14	146 700	143 400	140 000	136 600	133 300	129 900	126 600	123 200
14×16	167 700	163 700	160 000	156 100	152 300	148 500	144 600	140 800
14×18	188 600	184 300	180 000	175 700	171 400	167 000	162 700	158 400
16×16	193 300	189 400	185 600	181 800	177 900	174 100	170 200	166 400
16×18	217 400	213 100	208 800	204 500	200 200	195 800	191 500	187 200
18×18	246 200	241 900	237 600	233 300	229 000	224 600	220 300	216 000
Size	6 ft.	8 ft.	10 ft.	12 ft.	14 ft	16 ft.	18 ft.	20 ft.

CRYOSCOPIC EXPERIMENTS WITH THE ALUMINATES AND BORATES OF THE ALKALI METALS.

By A. A. NOYES, Ph.D., and W. R. WHITNEY, S.B.

Received May 28, 1894.

It is the purpose of this article to present the results of some experiments made with the view of determining the composition of the above mentioned salts in solution by means of the freezing point method. We will first describe the experiments with the aluminates.

It has already been established by the researches of Cavazzi[1] that, when metallic aluminum dissolves in sodium or potassium hydrate solution, one atom of aluminum is dissolved for every molecule of the alkali present, indicating that the compound formed contains the same number of atoms of the elements aluminum and sodium or potassium. Moreover, Prescott[2] found by titrating a solution of an aluminum salt with potassium or sodium hydrate solution, that the precipitate first formed went into solution upon the addition of one molecule of the alkali for each molecule of aluminum hydrate (AlO_3H_3) precipitated. And finally, Lyte[3] has shown that when a solution of aluminum sulphate is added to one of sodium aluminate the relative weights of the two substances required to precipitate each other correspond nearly to the molecular ratio

$$Al_2(SO_4)_3 : 3Na_2Al_2O_4.$$

There is therefore no doubt as to the atomic proportions of the elements in the aluminates, but there is no evidence to show that the correct formula may not be a multiple or sub-multiple of that commonly adopted, $Na_2Al_2O_4$. This can be decided, however, with the help of the recent methods of determining molecular weights in solution; for example, if aluminum is dissolved in sodium hydrate solution

[1] Gazzetta chimimica italiana, 15, 205.
[2] Journal of the American Chemical Society, 2, 27.
[3] Chemical News, 51, 109.

with the formation of the compound $Na_2Al_2O_4$, there would result in place of two molecules of sodium hydrate one of $Na_2Al_2O_4$; or, more correctly, taking into account the electrolytic dissociation, in place of four molecules, 2Na and 2(OH), there would be formed three, 2Na and Al_2O_4; and in a similar way for any higher multiple of $NaAlO_2$ there would be a still greater reduction in the number of molecules. If, however, the molecular composition is $NaAlO_2$ itself, there would evidently be no change in the number of molecules.

The most convenient method in this case, and the one we employed for determining the relative numbers of molecules, is that dependent on the change of freezing point of solutions. Experiments were made with both sodium and potassium hydrates at different dilutions and with varying proportions of aluminum. Standardized solutions of the alkaline hydrates were prepared from samples purified by alcohol, and weighed portions of aluminum foil were dissolved in them. The freezing points of these solutions were determined with the ordinary Beckmann apparatus. The following table contains the results:

	Solution.	Freezing point.
1	KOH (concentration, 0.227 normal)	— 0.790°
	KOH + $\frac{1}{3}$ Al	0.795
	KOH + $\frac{2}{3}$ Al	0.785
	KOH + Al	0.790
2	KOH (concentration, 0.465 normal)	— 1.660
	KOH + $\frac{1}{3}$ Al	1.660
	KOH + $\frac{1}{2}$ Al	1.665
	KOH + $\frac{2}{3}$ Al	1.665
3	NaOH (concentration, 0.511 normal)	— 1.715
	NaOH + $\frac{2}{3}$ Al	1.715
	NaOH + Al	1.700
4	KOH (concentration, 0.233 normal)	— 0.830
	KOH + $\frac{1}{2}$ AlO_3H_3	0.830

An examination of the above table shows that the freezing point of the alkali solutions is not appreciably changed by dissolving aluminum in them, even to saturation. The composition of the aluminate in solution is, therefore, $MAlO_2$, or a hydrate of this, as MH_2AlO_3, and the aluminum in it is trivalent, not quadrivalent.

The solution measured in the last experiment of the table was prepared by saturating potassium hydrate solution with washed, freshly precipitated aluminum hydrate. As in the case where metallic aluminum was dissolved, the freezing point of the alkali solution was unaffected. A determination of the aluminum dissolved in it showed that only one half as many molecules of aluminum hydrate AlO_3H_3 were dissolved as there were molecules of sodium hydrate in the solution, instead of an equal number, as in the case of the metallic aluminum and in the case of Prescott's experiments with aluminum hydrate. This result was confirmed by several experiments made at different temperatures, and indicates that the aluminum hydrate undergoes some change affecting its solubility, perhaps a dehydration, in the process of washing.

Experiments with the Borates. — The existence of variously constituted salts of boric acid makes their investigation by the cryoscopic method of especial interest. A single determination has been made in the case of borax by Raoult,[1] who found the molecular lowering to be unusually large (66°), and concluded from it that it is decomposed by water into sodium hydrate and an acid borate; but Shields[2] has since shown that borax, even in .03 molecular solution, is less than 1 per cent. hydrolyzed, so that this explanation is incorrect. We have, as in the experiments with aluminum, dissolved different weighed quantities of recrystallized boric acid in solutions of the alkalies and have taken the freezing points. The results are contained in the following table.

[1] Annales de chimie et de physique (6), **2**, 83; **4**, 420.
[2] Zeitschrift für physikalische Chemie, **12**, 176.

	Solution.	Freezing point.
1	KOH (concentration, 0.233 normal)	— 0.812°
	KOH + $\frac{1}{3}$ H_3BO_3	0.797
	KOH + $\frac{2}{3}$ H_3BO_3	0.769
	KOH + H_3BO_3	0.792
2	KOH (concentration, 0.465 normal)	— 1.660
	KOH + $\frac{1}{3}$ H_3BO_3	1.625
	KOH + H_3BO_3	1.505
	KOH + $2H_3BO_3$	1.200
	KOH + 2.5 H_3BO_3	1.210
	KOH + 2.5–3 H_3BO_3 (saturated)	1.220
3	NaOH (concentration, 0.511 normal)	— 1.760
	NaOH + H_3BO_3	1.540
4	NH_4OH (concentration, 0.391 normal)	— 0.740
	NH_4OH + H_3BO_3	1.010
	NH_4OH + $1.5H_3BO_3$	1.040
	NH_4OH + $2H_3BO_3$	1.050

We will consider first the experiments with potassium and sodium hydrates. In the case of the first series of experiments with the weaker solution of potassium hydrate, the addition of boric acid, even of an equal molecular quantity, had hardly an appreciable effect on the freezing point. The stronger solutions of potassium and sodium hydrates showed, with the same proportion of boric acid, a distinct rise in the freezing point, though not a very considerable one. We must then conclude that the number of molecules has not been much changed by the addition of this quantity of boric acid, and that therefore the composition of the borate in this solution is chiefly MBO_2 or MH_2BO_3. Yet the rise observed in the case of the stronger solution corresponds to a not inconsiderable proportion of a more complex borate.

The addition of the second molecule of boric acid, however (series 2), caused the freezing point to rise to about three fourths of its value in the case of pure potassium hydrate solution, indicating that the number of molecules has decreased in the same proportion. It is evident that, if the second molecule of boric acid remained uncombined in the solution, an increased lowering would have been the result. If it had simply added itself to the molecule of borate already present, there would have been no change whatever in the freezing point. The significance of this rise in freezing point then is, that this second boric acid molecule has caused the molecules originally present to associate, and has added itself to the aggregate thus formed. Furthermore, the complex molecule so produced must contain *four* boric atoms; for suppose two molecules of the original monoborate united with one of boric acid, then there would be left one molecule of uncombined boric acid whose presence would just compensate the reduction in the number of molecules arising from the assumed union, and only if this molecule of boric acid forms a part of the complex molecule can the freezing point rise. Moreover, the amount of the rise corresponding to the formation of this tetraborate is easily deduced from the following considerations — two molecules of potassium hydrate in solution give rise to four molecules by reason of the electrolytic dissociation; the tetraborate, on the other hand, would dissociate into three molecules, the two potassium ions and the acid ion of the tetraboric acid, corresponding to the reduction of three fourths actually observed in the lowering of the freezing point.

The addition of more than two molecules of boric acid, as shown by the table, had no further effect on the freezing point. This boric acid has, therefore, added itself to the tetraboric ion, producing still more complex molecules, whose composition, however, is not determined.

It is interesting to note that these results are in accordance with the thermo-chemical measurements of Thomsen[1] reproduced here:

$$(NaOHAq, H_3BO_3Aq) = 100K$$
$$(NaOHAq, 2H_3BO_3Aq) = 111K$$
$$(NaOHAq, 4H_3BO_3Aq) = 129K$$
$$(NaOHAq, 6H_3BO_3Aq) = 136K.$$

The fact that the evolution of heat does not cease when one

[1] Thermochemische Untersuchungen, I, 206.

molecule of boric acid has been added, corresponds to the formation of the more complex molecules shown to exist by the freezing point determinations.

We have still to refer to the experiments with ammonia. This being a very slightly dissociated base, the lowering of the freezing point would be nearly doubled for one molecule of acid added, if the acid remained uncombined or if ammonium monoborate were formed. In fact, however, the lowering was increased only one third, showing that a more complex borate was formed. Since the phenomenon is in this case no doubt complicated by hydrolysis, which must be here much more considerable than with the stronger bases, it is useless to attempt to draw a more definite conclusion in regard to its constitution.

The above results may be briefly summarized as follows: The aluminates of the alkalies in solution have the composition $MAlO_2$ or a hydrate of this. The borates have a corresponding composition as long as the number of molecules of boric acid does not exceed that of the molecules of the alkaline hydrate. The composition of the salt formed when two molecules of acid are present is $M_2B_4O_7$ (or its hydrate). Subsequent molecules of boric acid add themselves directly to the tetraboric acid ion already present, with formation of a di-sodium or potassium salt of a still more complex boric acid.